CSE544
Data Management

Lecture 9
Query Optimization – Part 1

Announcements

- Project proposal is due tonight
  - Submit via gitlab
  - Also update the title on the spreadsheet.
- HW2 is due on Wednesday
- Wednesday: Kyle's lecture about HW3
- Review 3 due next Wednesday.

Query Optimization

Three major components:

1. Search space — today
2. Cardinality and cost estimation — Monday
3. Plan enumeration algorithms — Wednesday

Search Space

Refers to the set of all possible alternate plans that the optimizers may explore

- Access Path Selection: how to use indices
- Rewrite Rules: what identities the optimizer applies

Access Path

Access path: implements a selection $\sigma_P(R)$

(P is sometimes called *search argument* SARG)

- A file scan, or
- An index *plus* a matching selection condition

Supplier(sid, sname, scity, sstate)

Access Path Selection

```
SELECT * FROM Supplier
WHERE sid > 300 ∧ scity='Seattle'
```

Indices:

B+-tree on sid; clustered

B+-tree on scity; unclustered

Access Path Selection

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Which access path should we use?

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Which access path should we use? Depends on stats

Access Path Selection

```
SELECT * FROM Supplier
WHERE sid > 300 ∧ scity='Seattle'
```

B(Supplier) = 100
T(Supplier) = 1000
V(Supplier,scity) = 20
Max(Supplier, sid) = 1000
Min(Supplier,sid) =1

Indices:

B+-tree on sid; clustered

B+-tree on scity; unclustered

Which access path should we use? Depends on stats

Supplier(sid, sname, scity, sstate)

Access Path Selecti

```
SELECT * FROM Supplier
WHERE sid > 300 ∧ scity='Seattle'
```

Number of distinct values of scity

B(Supplier)
T(Supplier) 1000
V(Supplier,scity) = 20
Max(Supplier, sid) = 1000
Min(Supplier,sid) =1

Indices:

B+-tree on sid; clustered

B+-tree on scity; unclustered

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1. Sequential scan: cost = 100

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B+-tree on sid; clustered
B+-tree on scity; unclustered

Which access path should we use? Depends on stats

1. Sequential scan: cost = 100
2. Index scan on sid: cost = 7/10 * 100 = 70

Access Path Selection

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Indices:

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Which access path should we use? Depends on stats

1. Sequential scan: cost = 100
2. Index scan on sid: cost = 7/10 * 100 = 70
3. Index scan on scity: cost = 1000/20 = 50

Access Path Selection

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SELECT * FROM Supplier
WHERE sid > 300 ∧ scity='Seattle'
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B(Supplier) = 100
T(Supplier) = 1000
V(Supplier,scity) = 20
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B+-tree on scity; unclustered

Which access path should we use? Depends on stats

1. Sequential scan: cost = 100
2. Index scan on sid: cost = 7/10 * 100 = 70
3. Index scan on scity: cost = 1000/20 = 50

Optimal

Rewrite Rules

Search space is defined by the set of rewrite rules that the optimizer implements

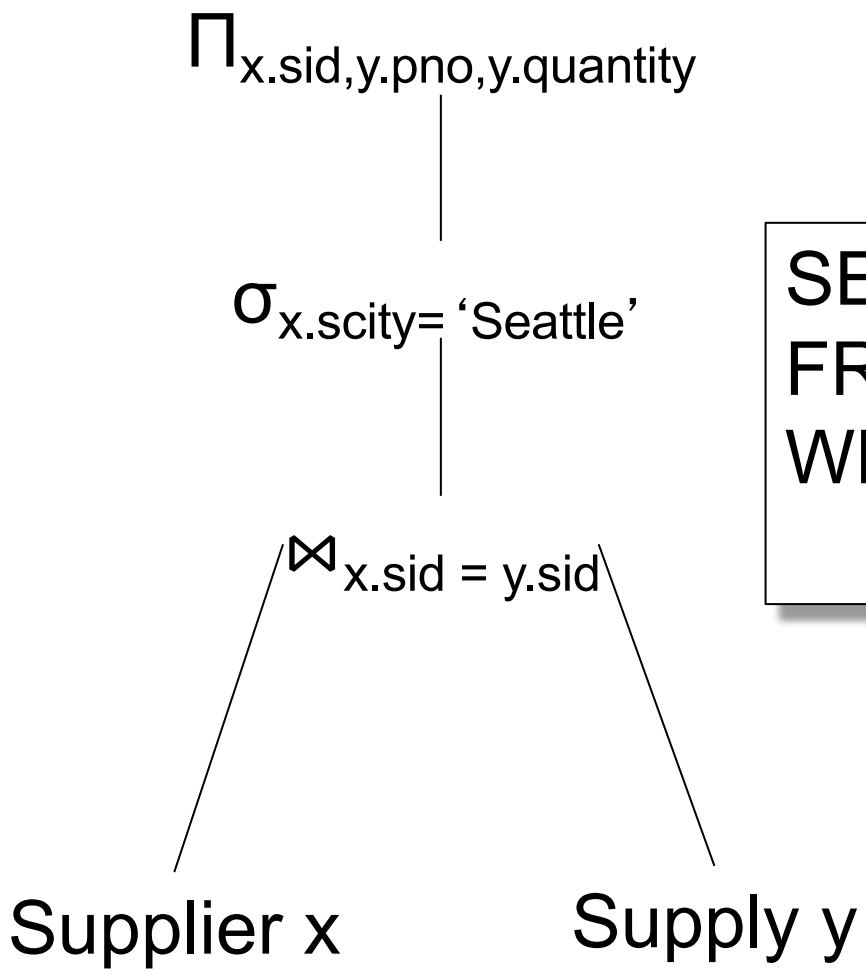
Supplier(sid, sname, scity, sstate)
Supply(sid, pno, quantity)

Example Optimization

```
SELECT x.sid, y.pno, y.quantity
FROM.   Supplier x, Supply y
WHERE x.sid = y.sid
        and x.scity = ‘Seattle’
```

Supplier(sid, sname, scity, sstate)
Supply(sid, pno, quantity)

Example Optimization

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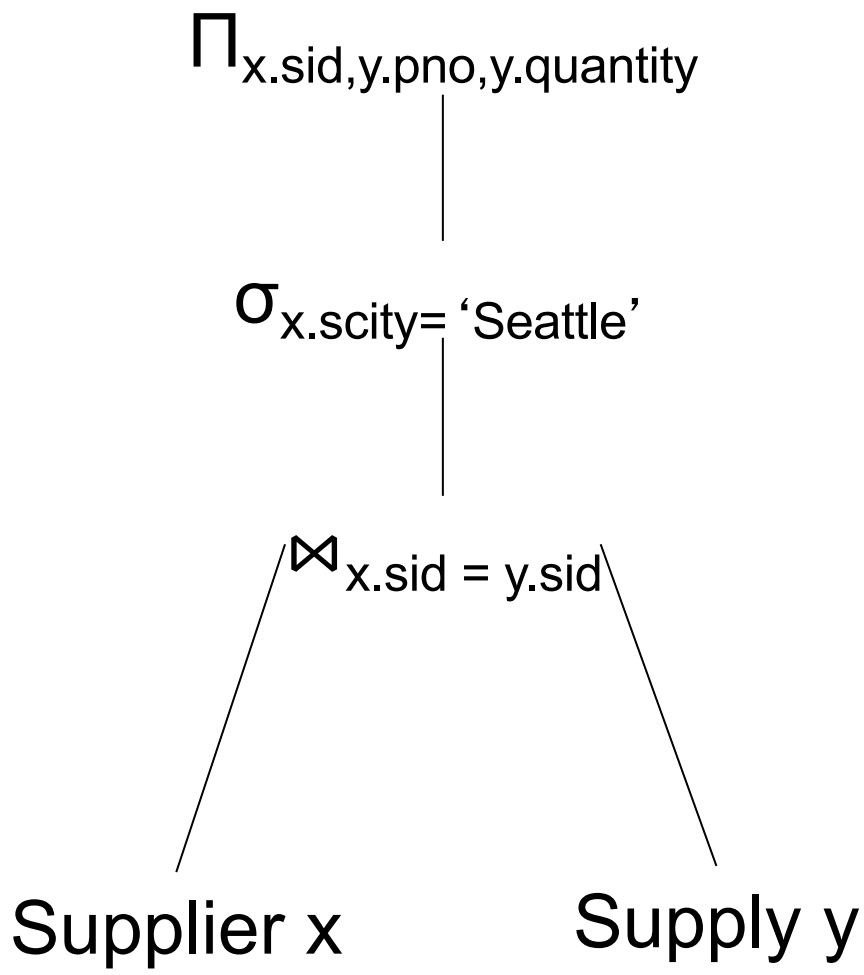
Supplier(sid, sname, scity, sstate)
Supply(sid, pno, quantity)

Push Selections Down



Supplier(sid, sname, scity, sstate)
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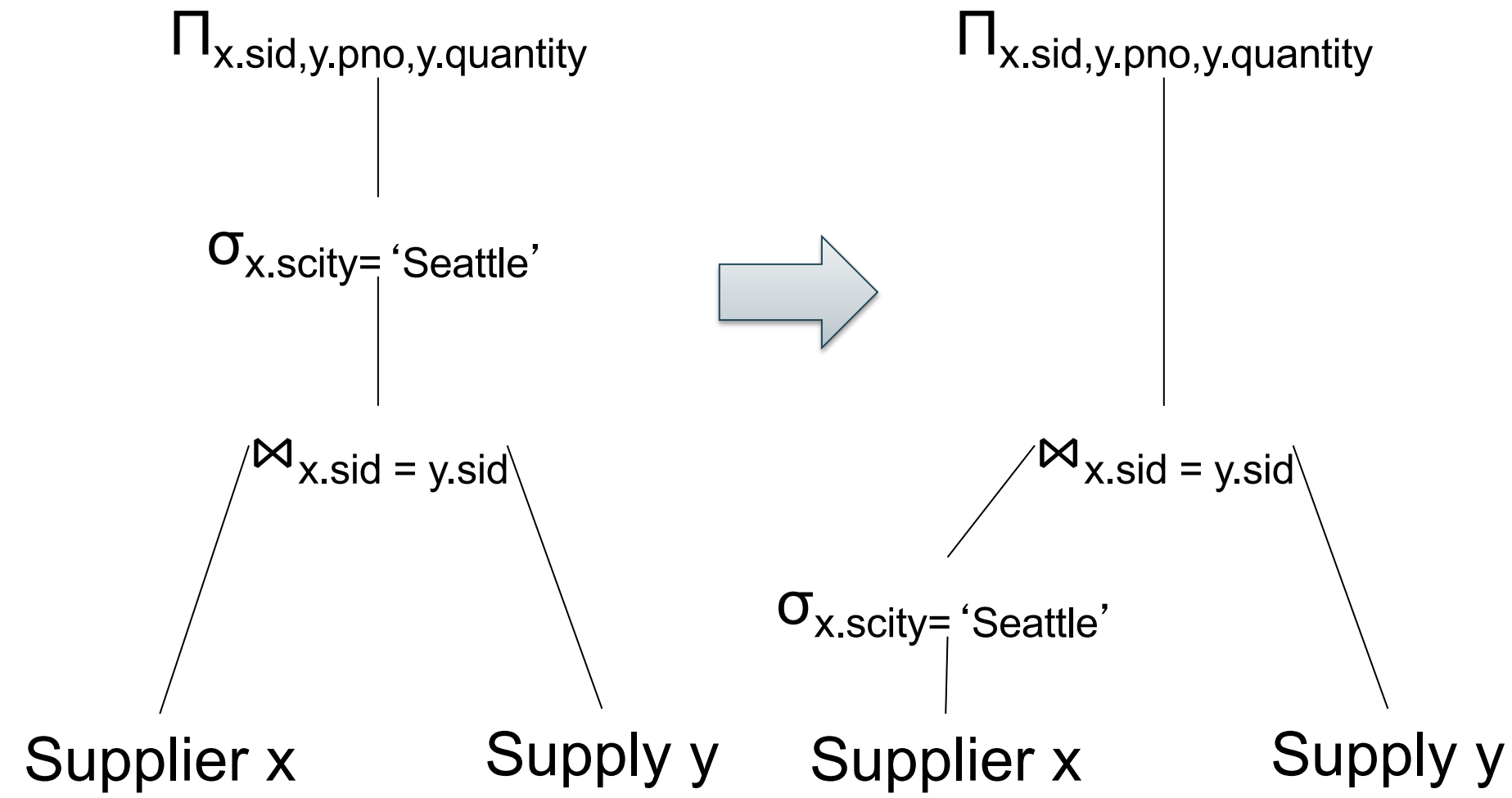

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Supply(sid, pno, quantity)

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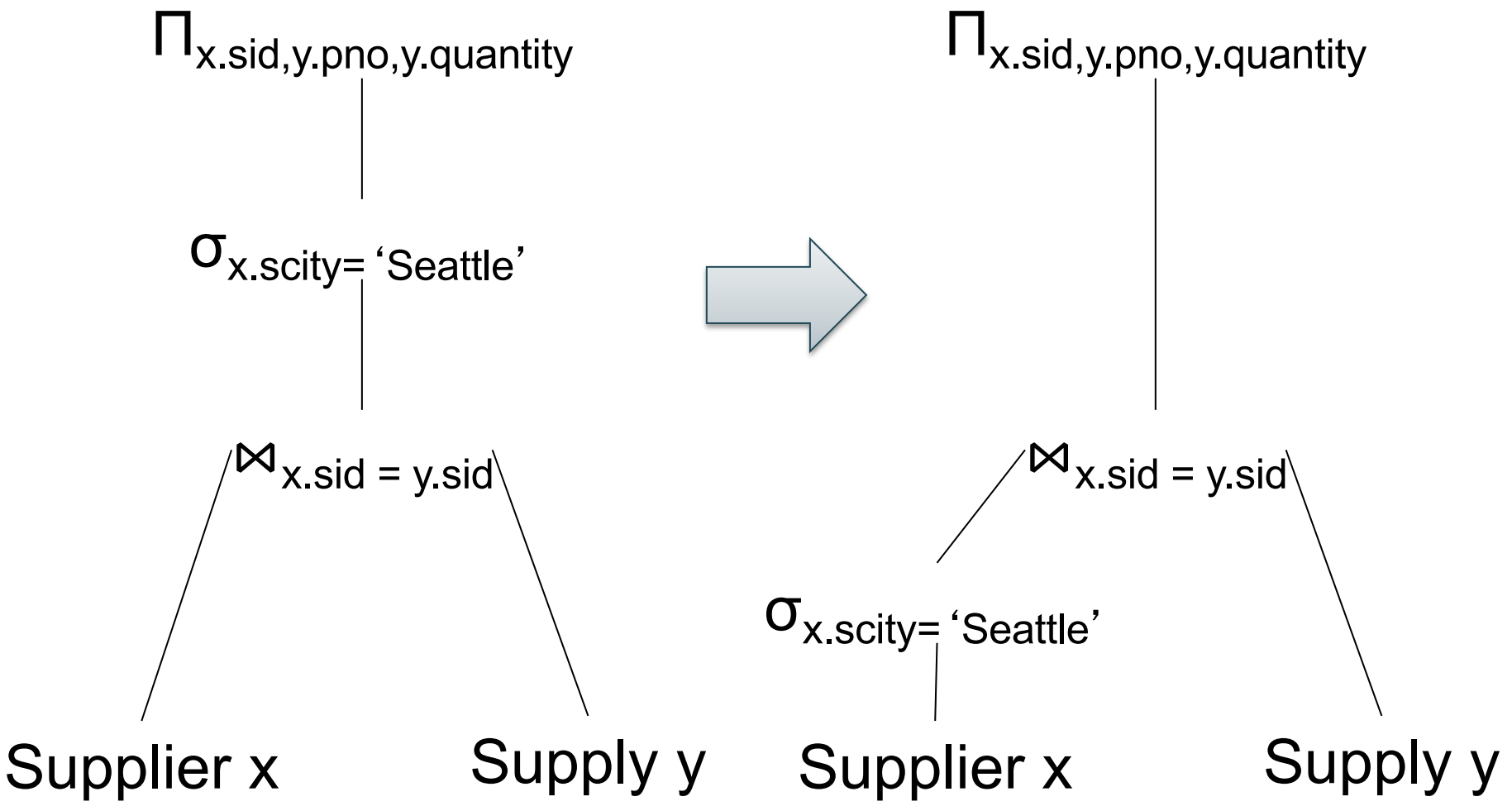
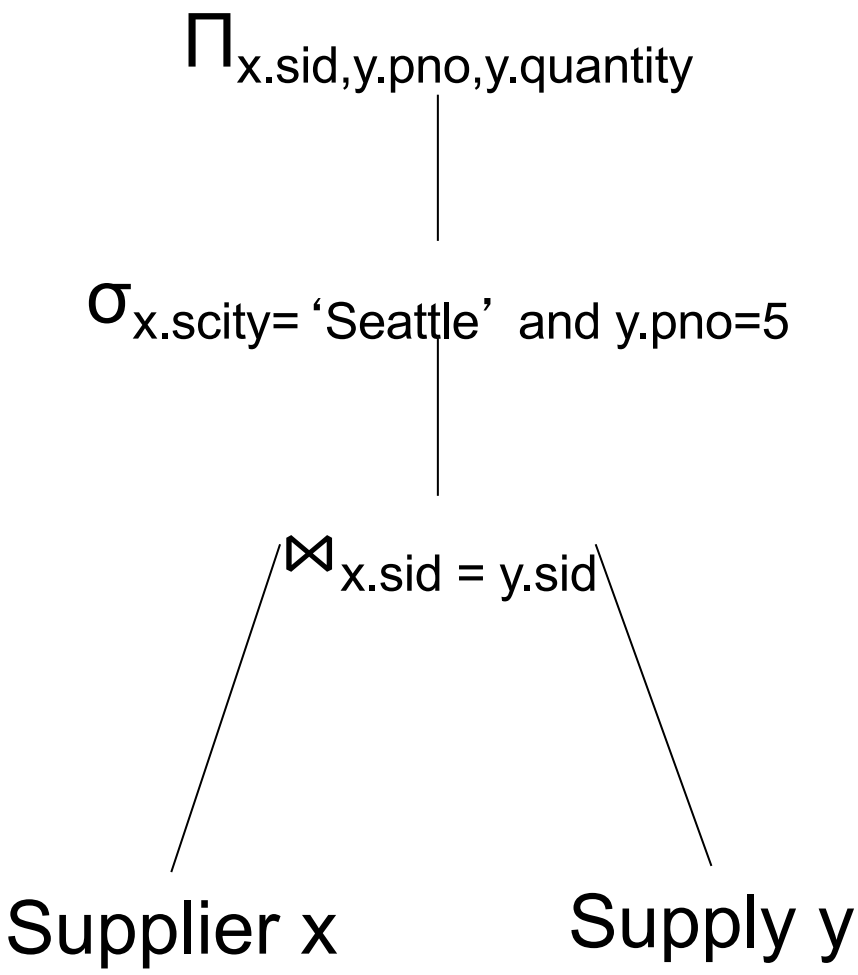


$\sigma_C(R \bowtie S) = \sigma_C(R) \bowtie S$ when C refers only to R

Supplier(sid, sname, scity, sstate)
Supply(sid, pno, quantity)

Push Selections Down



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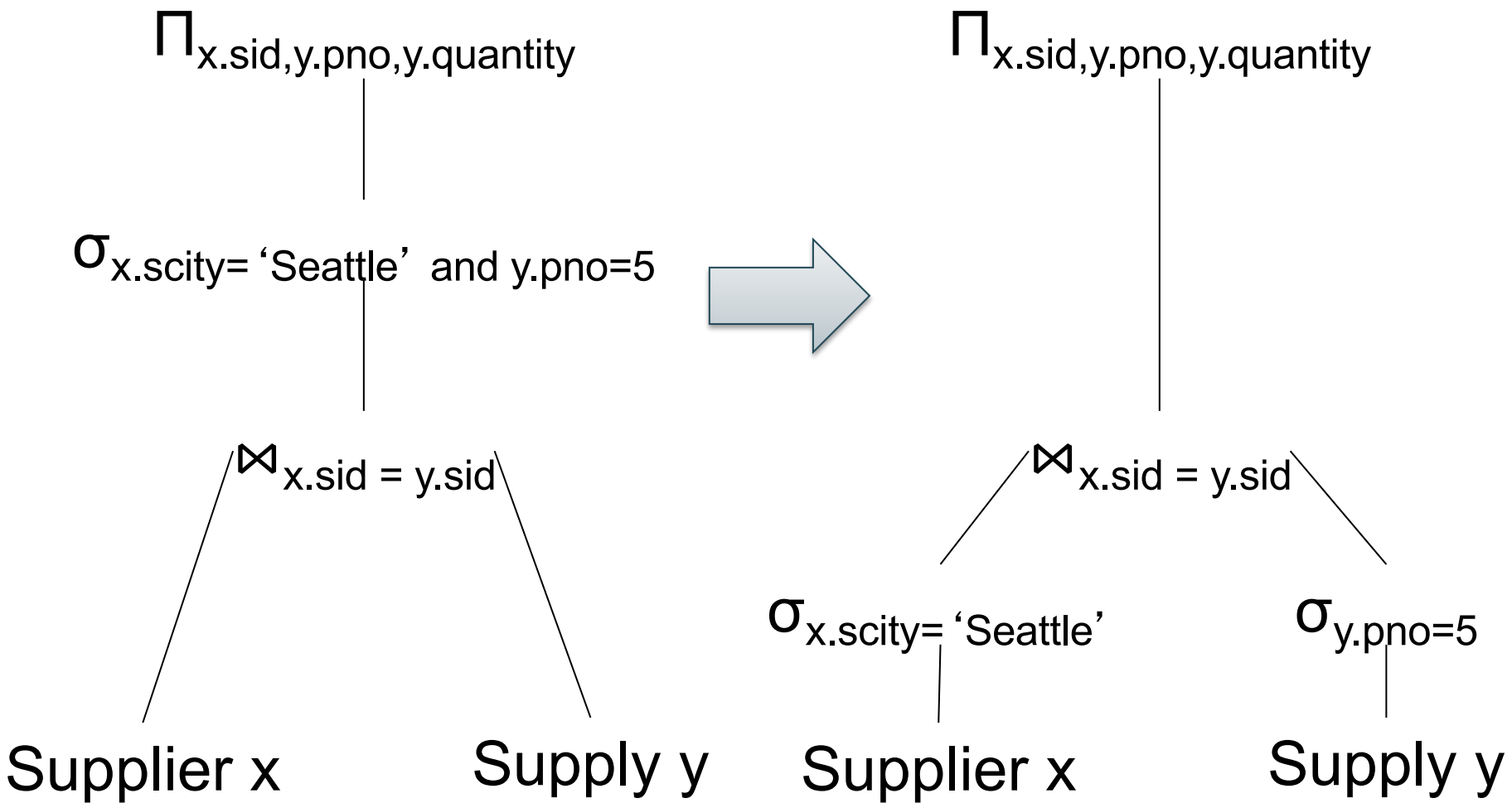
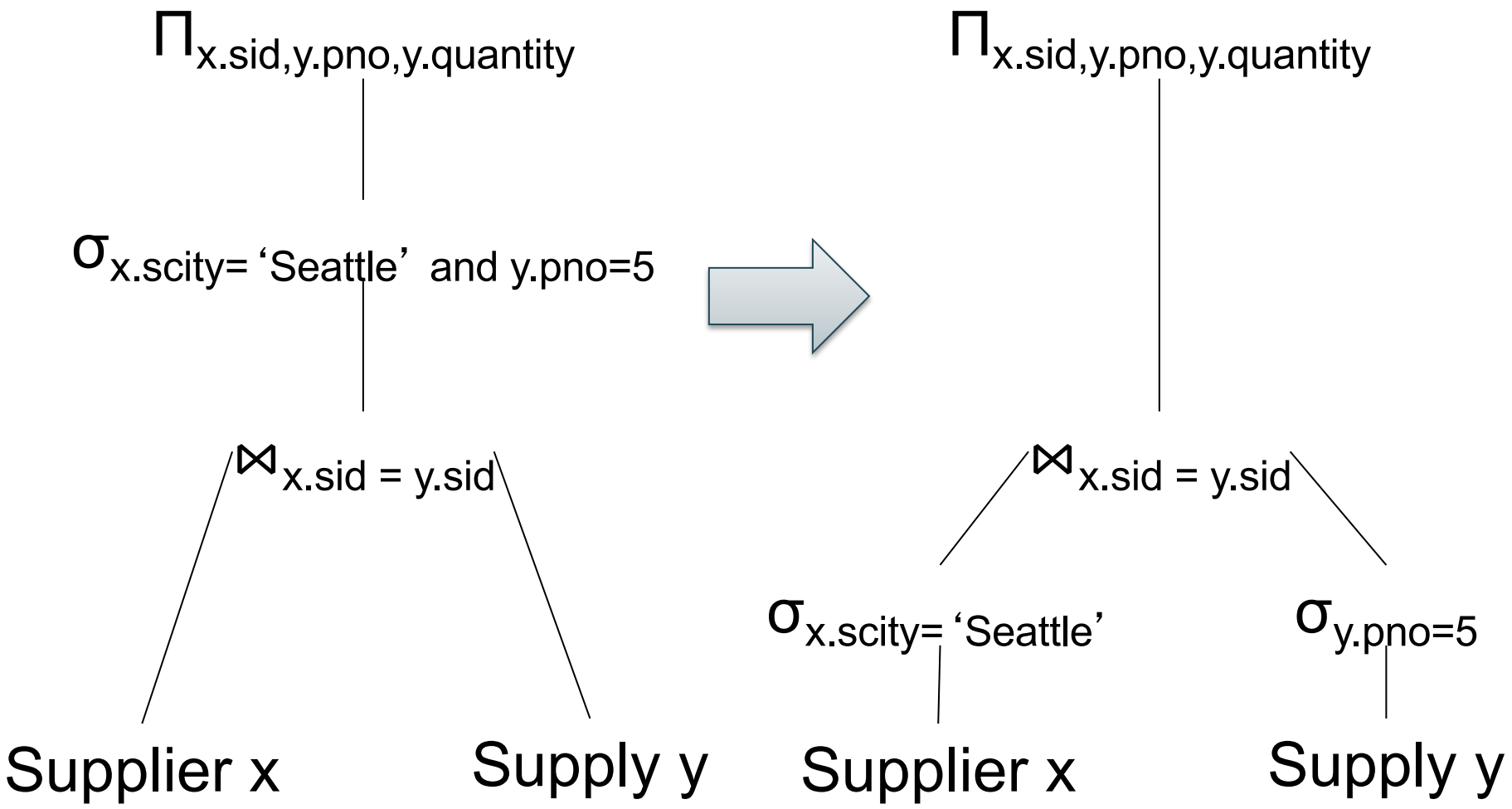


Supplier(sid, sname, scity, sstate)
Supply(sid, pno, quantity)

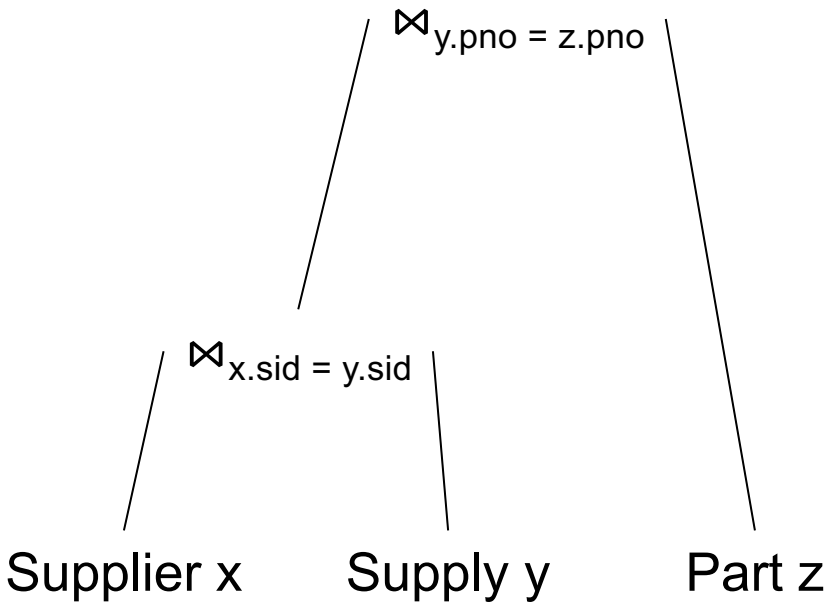
Push Selections Down



$$\sigma_{C1 \text{ and } C2}(R \bowtie S) = \sigma_{C1}(\sigma_{C2}(R \bowtie S)) = \sigma_{C1}(R \bowtie \sigma_{C2}(S)) = \sigma_{C1}(R) \bowtie \sigma_{C2}(S)$$

Supplier(sid, sname, scity, sstate)
Supply(sid, pno, quantity)
Part(pno, pname, pprice)

Join Reorder



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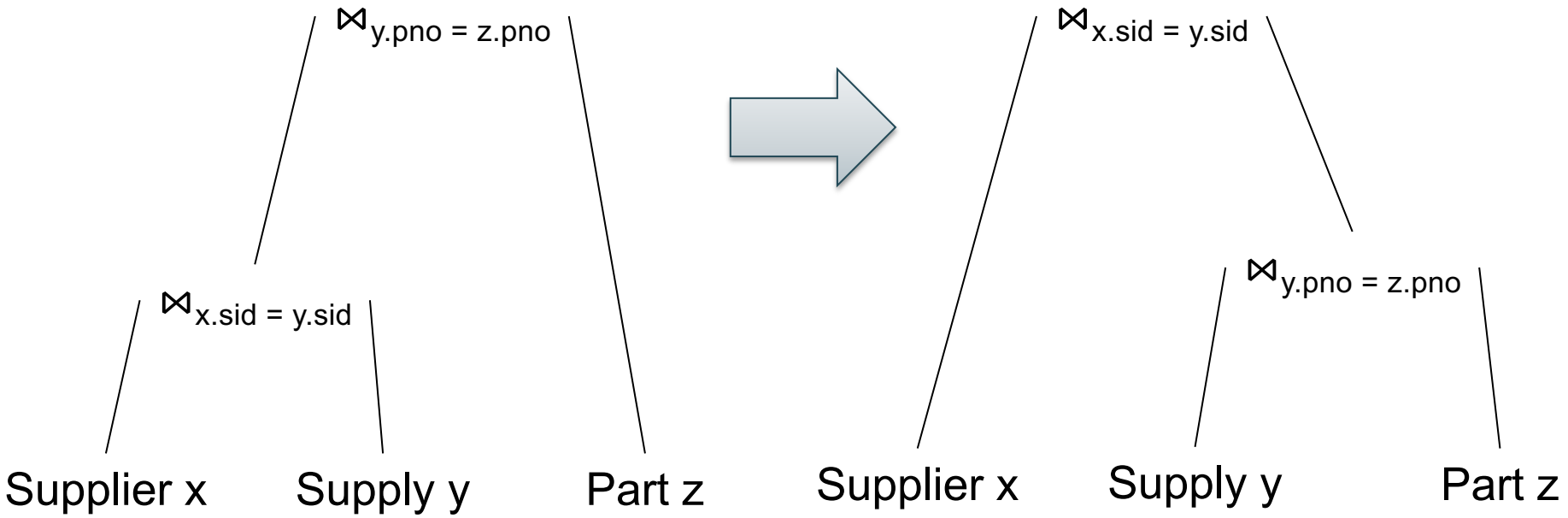

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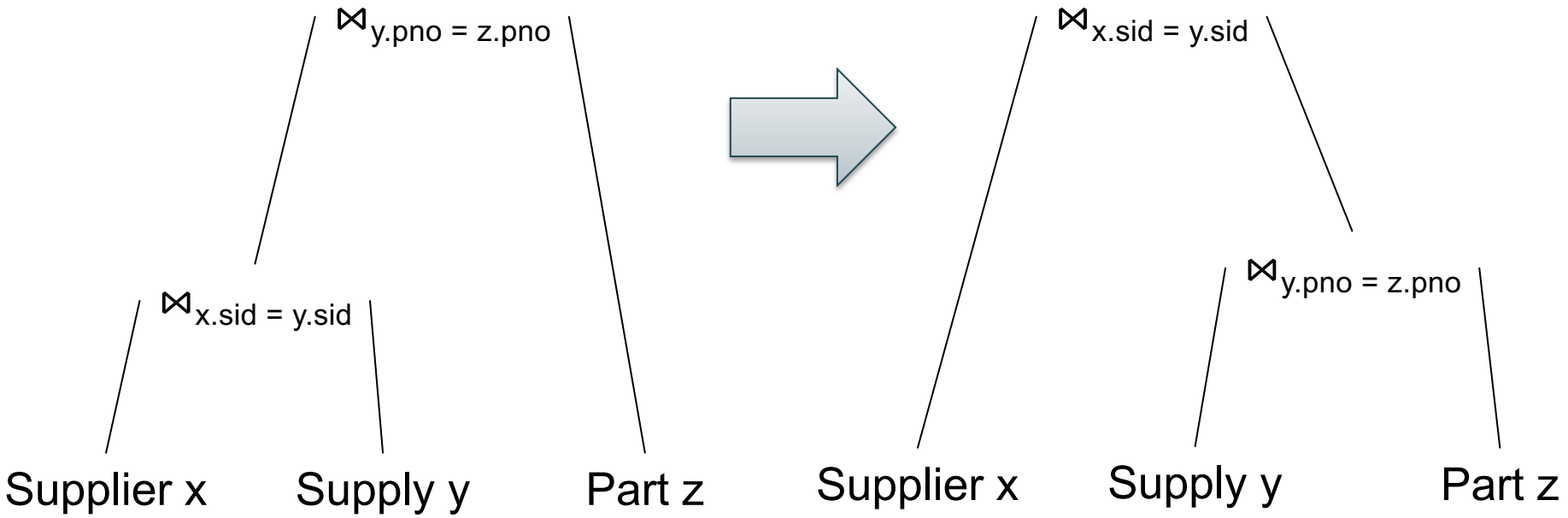
Join Reorder



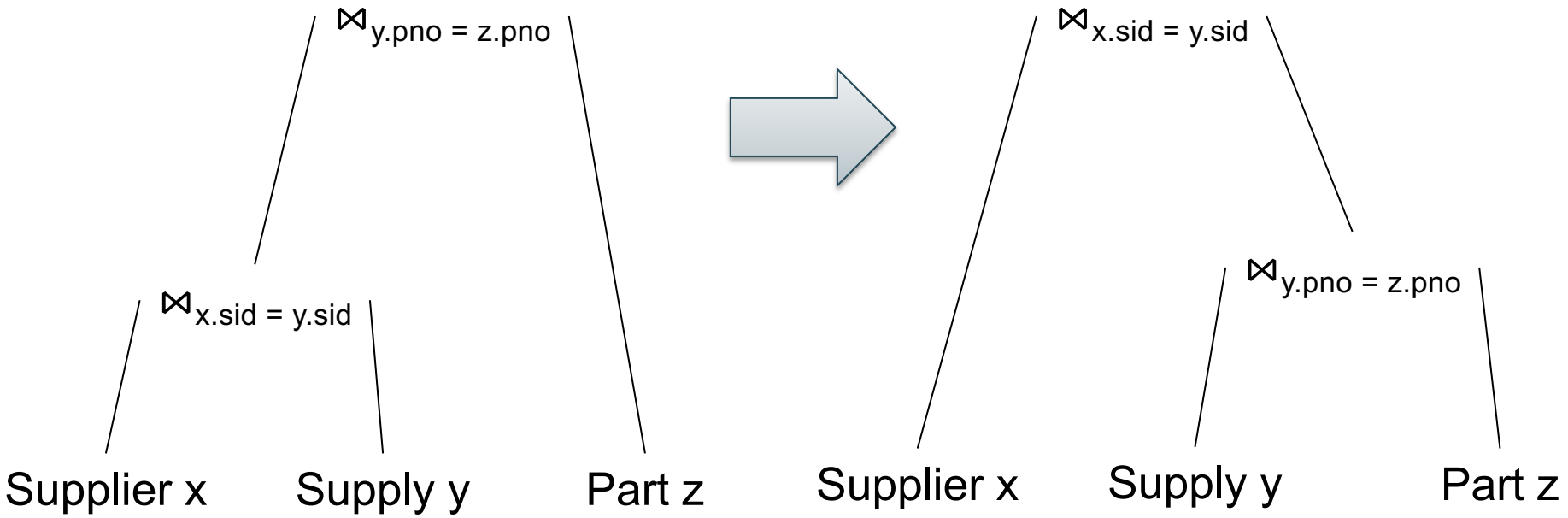
$$(R \bowtie S) \bowtie T = R \bowtie (S \bowtie T)$$

$$R \bowtie S = S \bowtie R$$

Supplier(sid, sname, scity, sstate)
Supply(sid, pno, quantity)
Part(pno, pname, pprice)

Join Reorder

Which plan is better?



$(R \bowtie S) \bowtie T = R \bowtie (S \bowtie T)$

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Supplier(sid, sname, scity, sstate)
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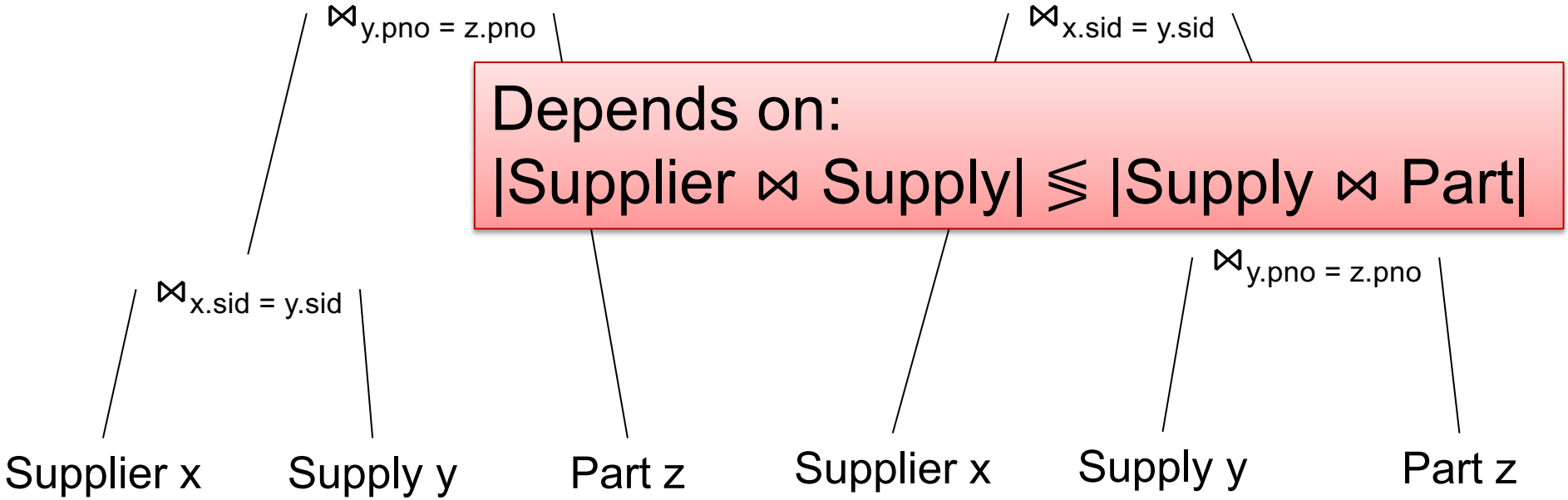


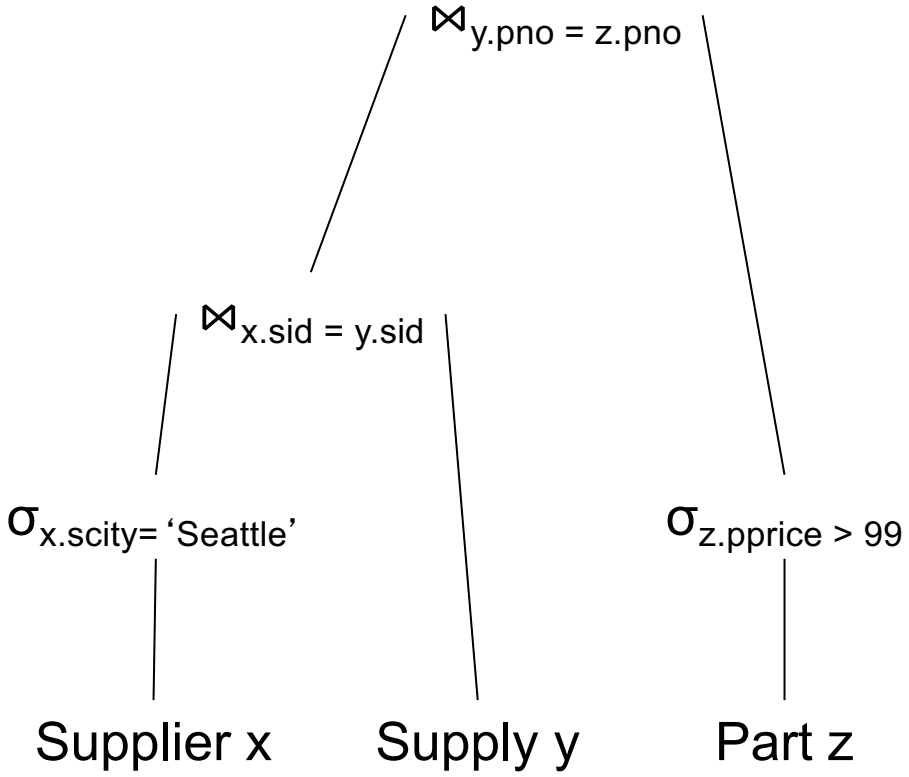
Depends on:
|Supplier ⋈ Supply| ⩽ |Supply ⋈ Part|

$(R \bowtie S) \bowtie T = R \bowtie (S \bowtie T)$

$R \bowtie S = S \bowtie R$

Supplier(sid, sname, scity, sstate)
Supply(sid, pno, quantity)
Part(pno, pname, pprice)

Join Reorder



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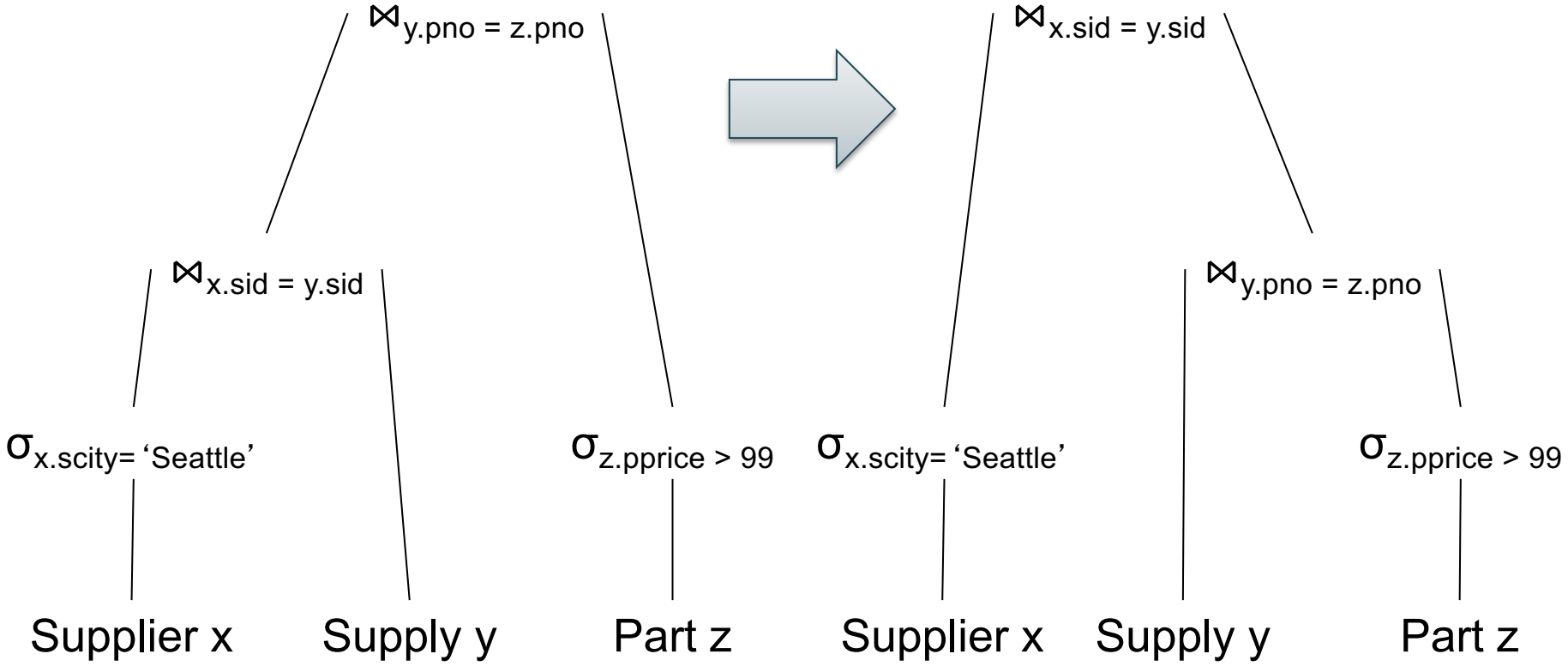

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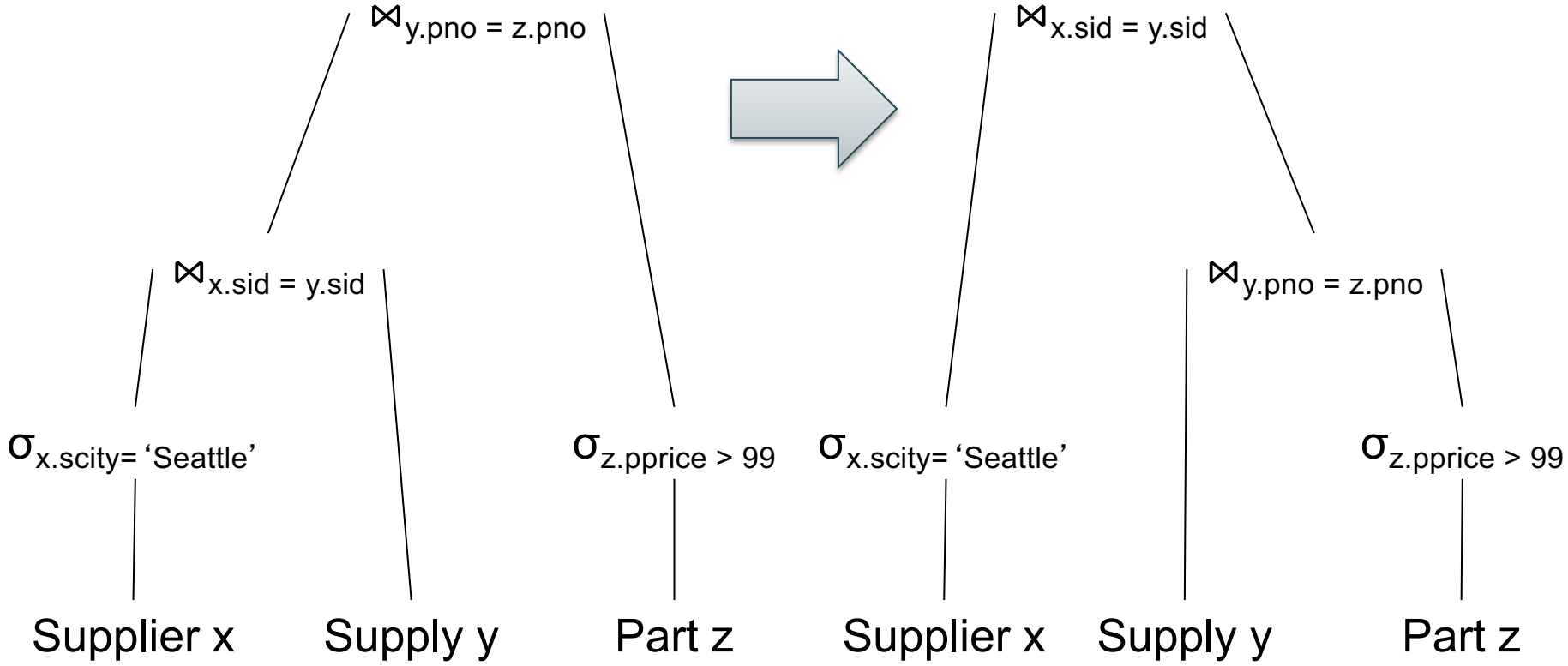

Lesson: need sizes of $\sigma_{x.scity= \text{'Seattle'}}$(Supplier), $\sigma_{z.pprice > 99}$(Part)

Discussion

- Both rewrite rules **and** cardinality estimations are needed for optimization
- They can be developed independently

- Next: a powerful optimization rule: aggregate pushdown or better known as generalized distributivity law

Motivation

- Try this in postgres

```
select count(*) from author;
```

Answer: 2652053
Time: 0.058 s

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select count(*) from author;
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select count(*) from publication;
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Answer: 5120896
Time: 0.062 s

Motivation

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select count(*) from author;
```

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Time: 0.058 s

```
select count(*) from publication;
```

Answer: 5120896
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```
select count(*) from author, publication;
```

Timeout!!!

Motivation

- Try this in postgres

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Time: 0.058 s

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select count(*) from publication;
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Answer: 5120896
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```
select count(*) from author, publication;
```

Timeout!!!

But 3rd query is simply the **product** of the first two!

Supplier(sid, sname, scity, sstate)
Supply(sid, pno, quantity)
Part(pno, pname, pprice)

Aggregate Push-down

```
SELECT x.sstate, sum(y.quanity*z.price)
FROM Supplier x, Supply y, Part z
WHERE x.sid = y.sid and y.pno = z.pno
GROUP BY x.sstate
```

Aggregate Push-down

Supplier(sid, sname, scity, sstate)
Supply(sid, pno, quantity)
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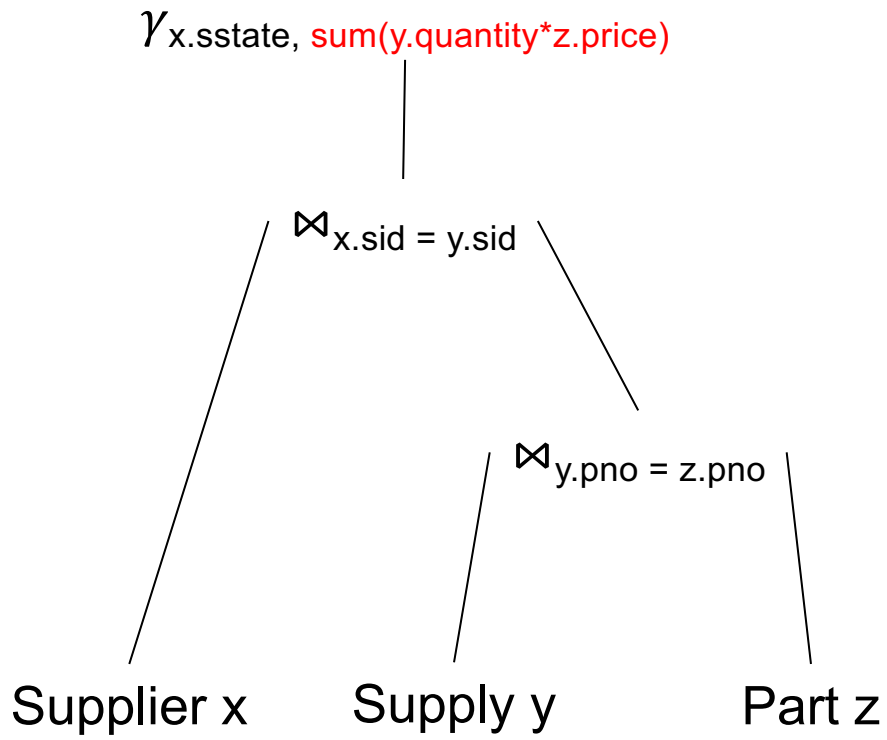


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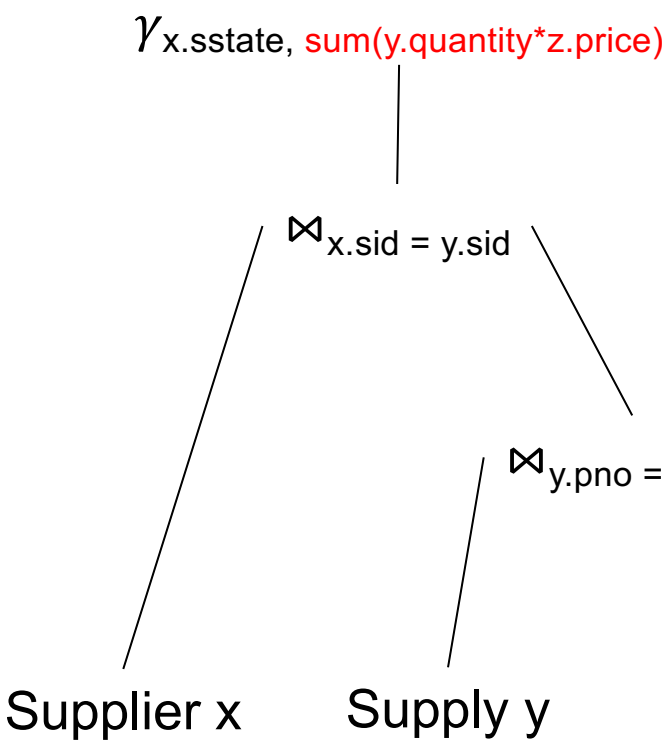

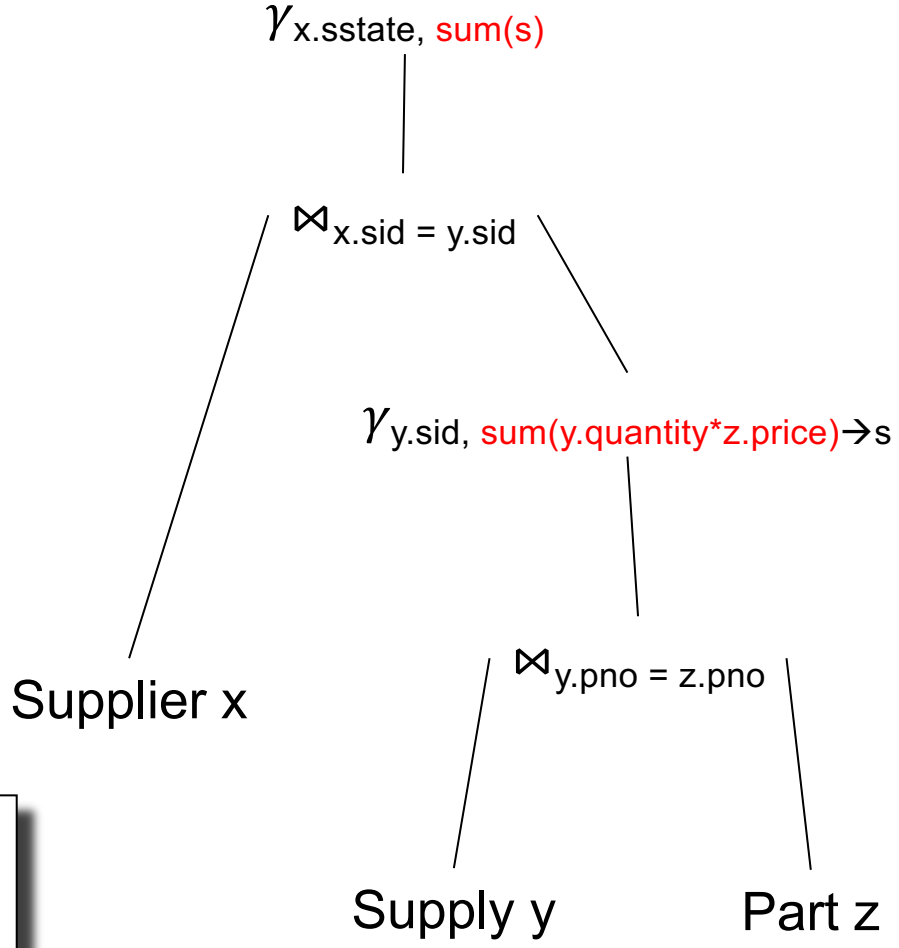


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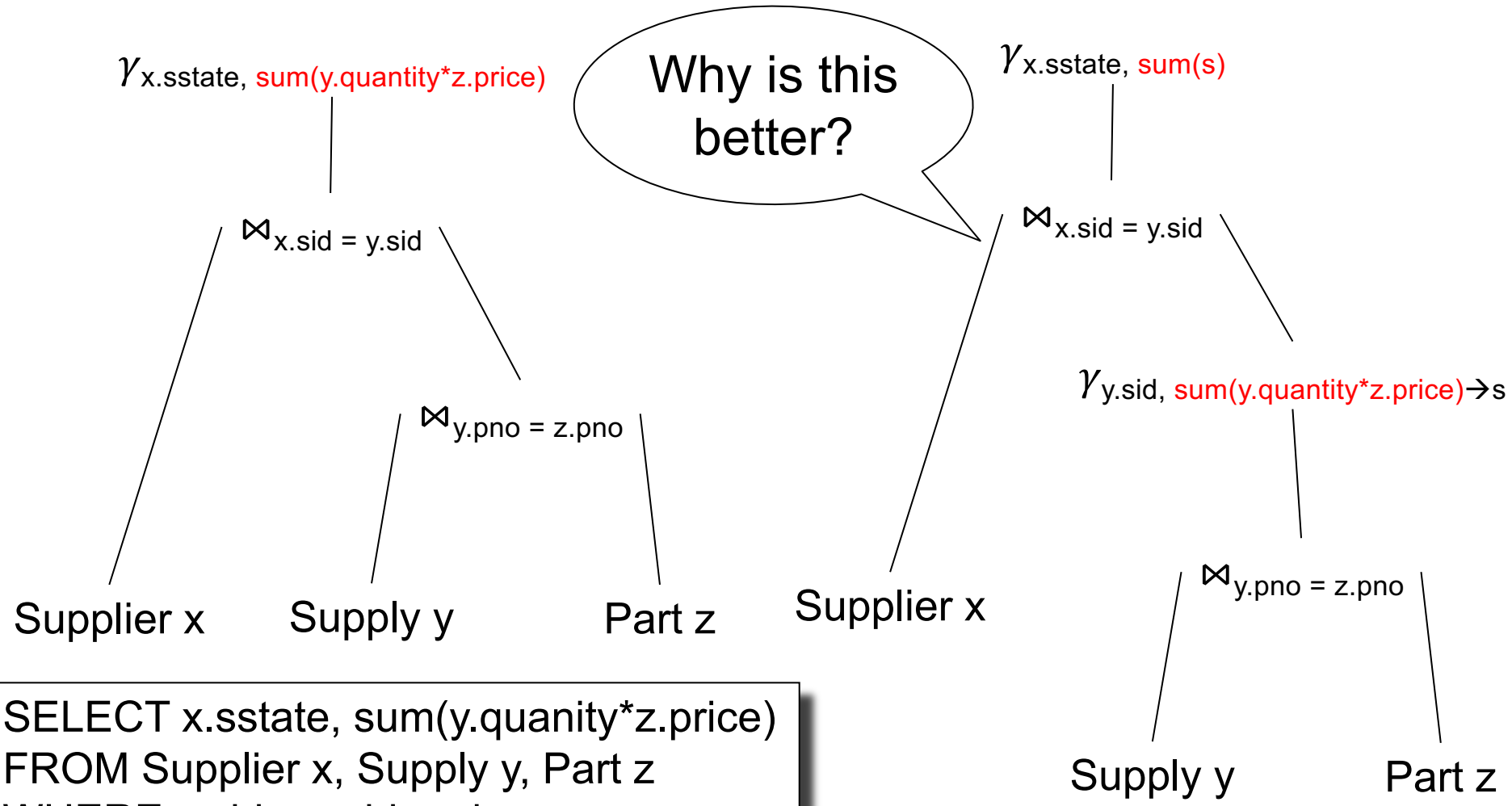


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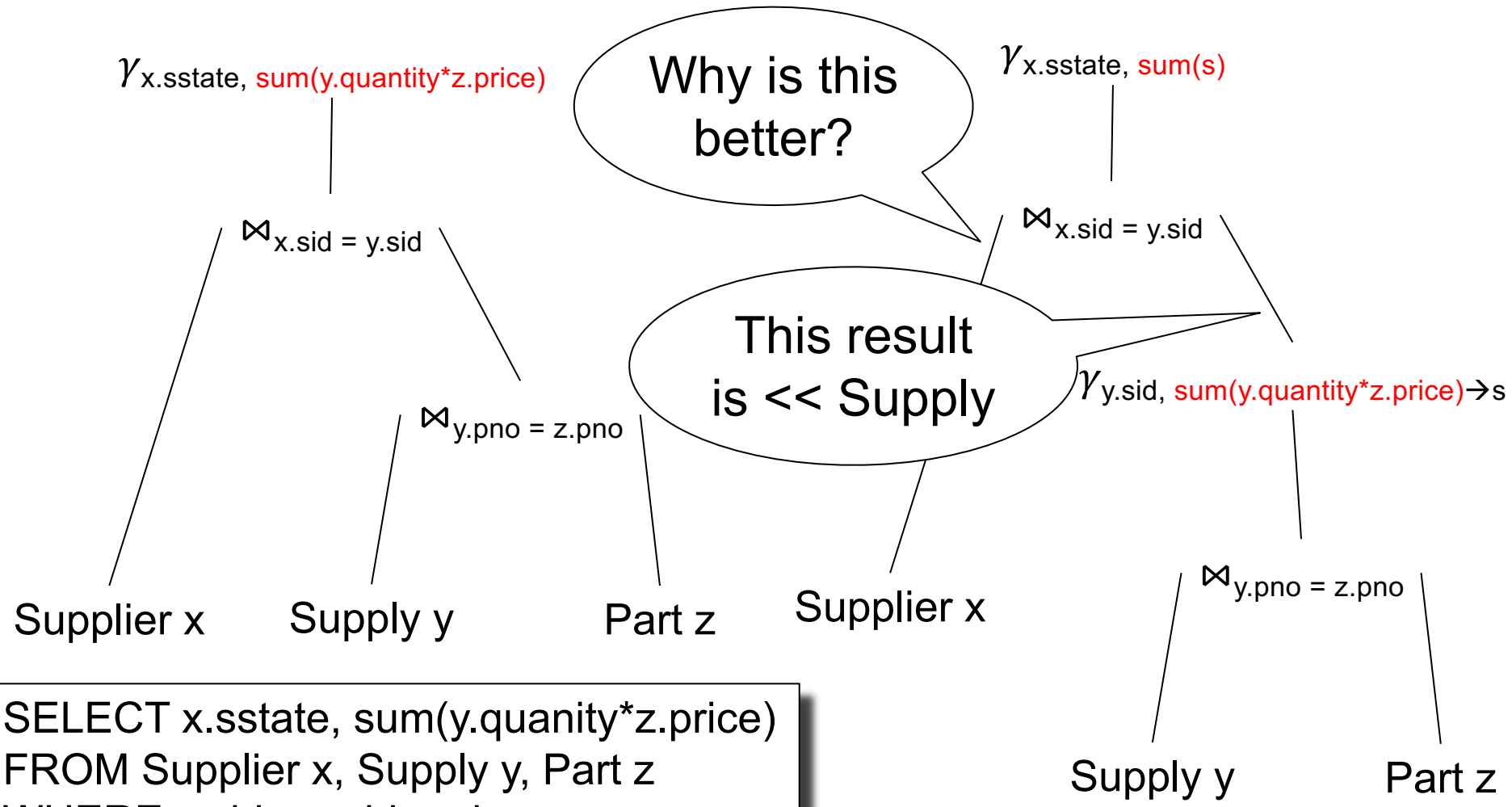


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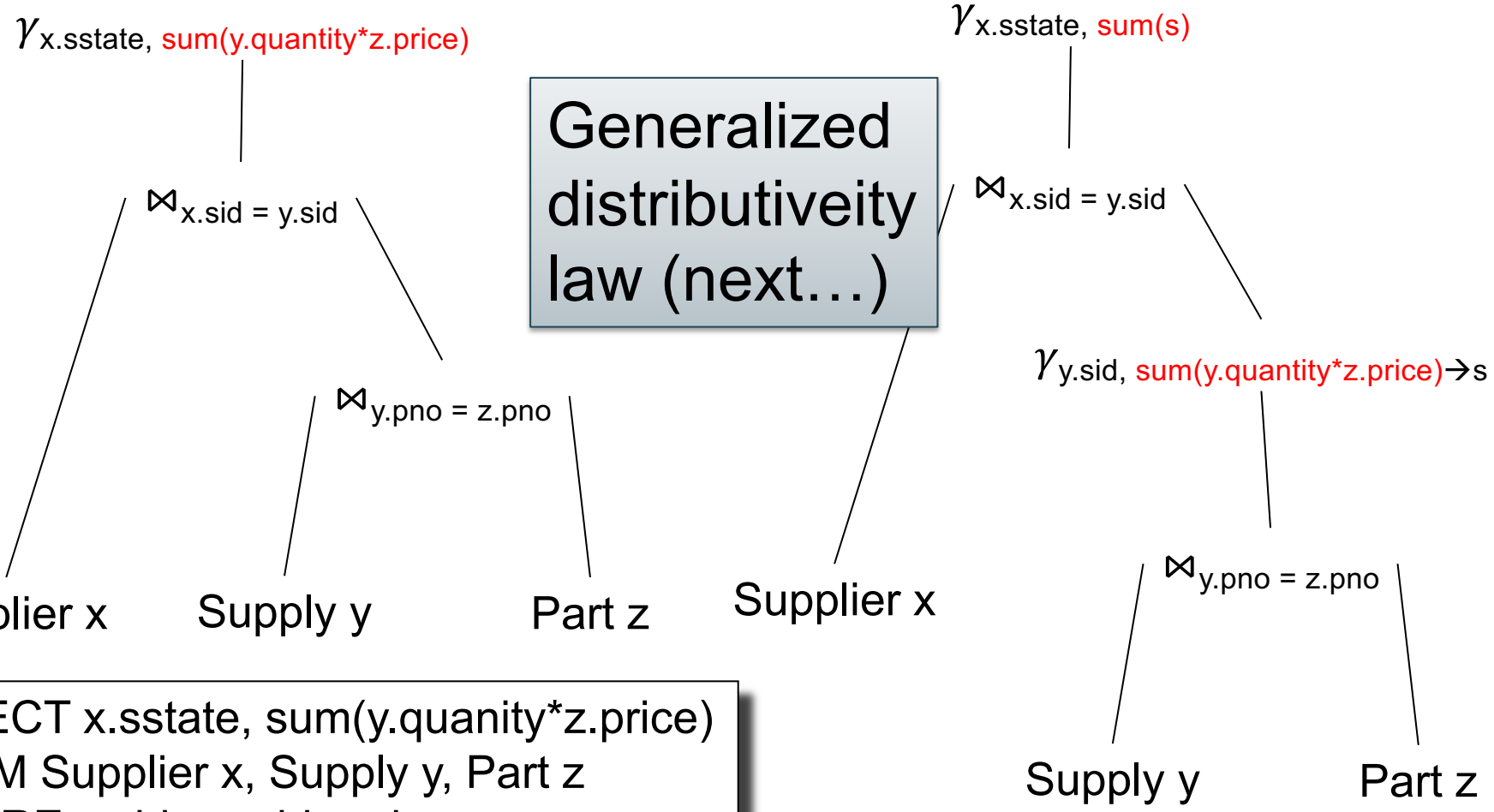


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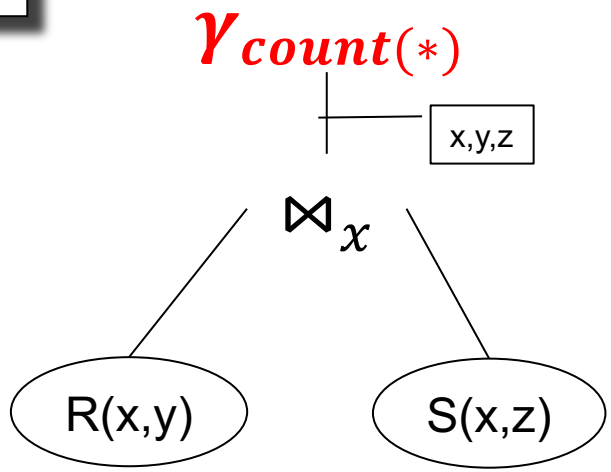
Generalized Distributivity Law

SELECT count(*) from R, S where R.x=S.x



Generalized Distributivity Law

SELECT count(*) from R, S where R.x=S.x

R:

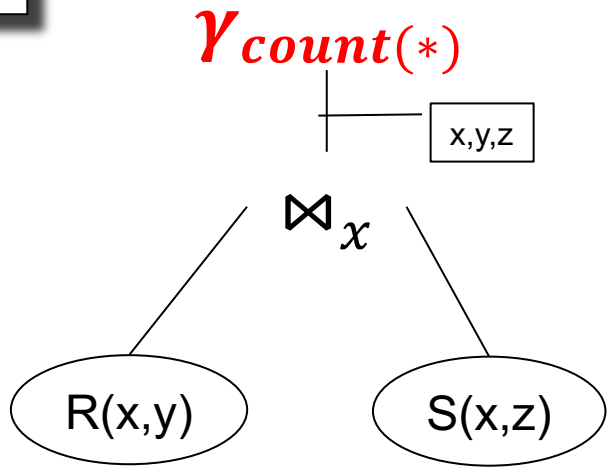
x	y
b	a
b	c
f	d
h	g

S:

x	z
b	g
b	k
h	m

Answer = 5

Runtime = ?????



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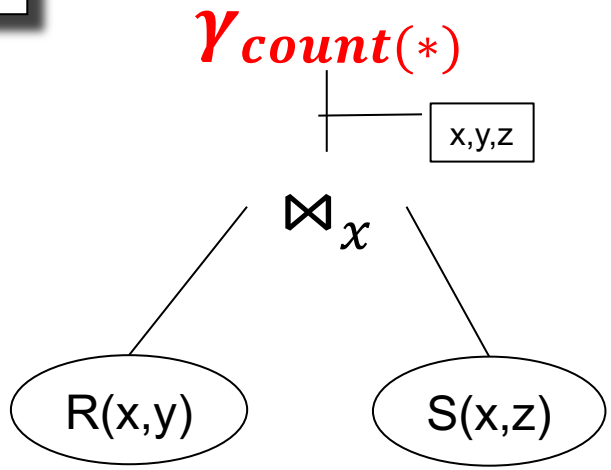
Runtime = $O(N^2)$



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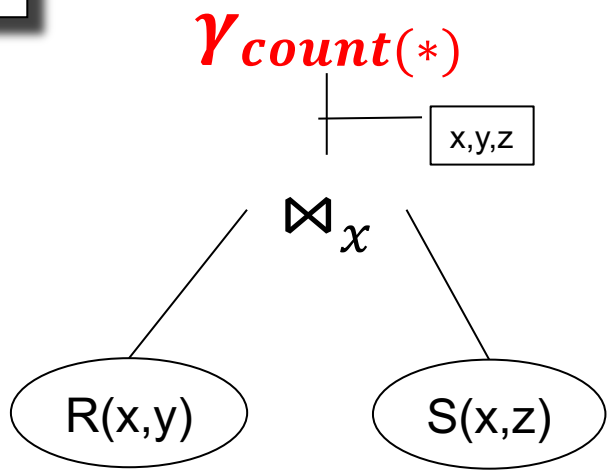

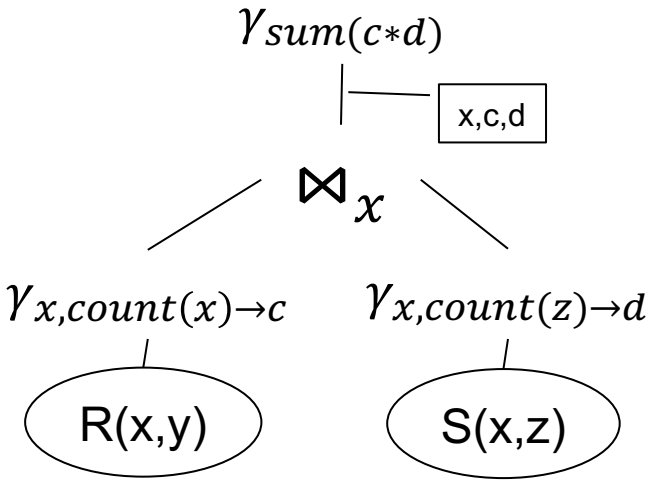

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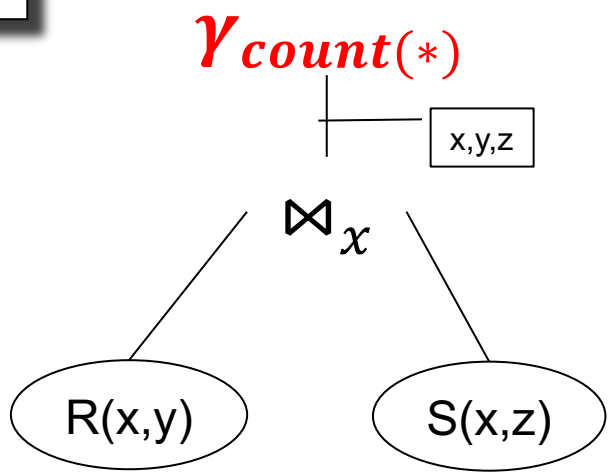

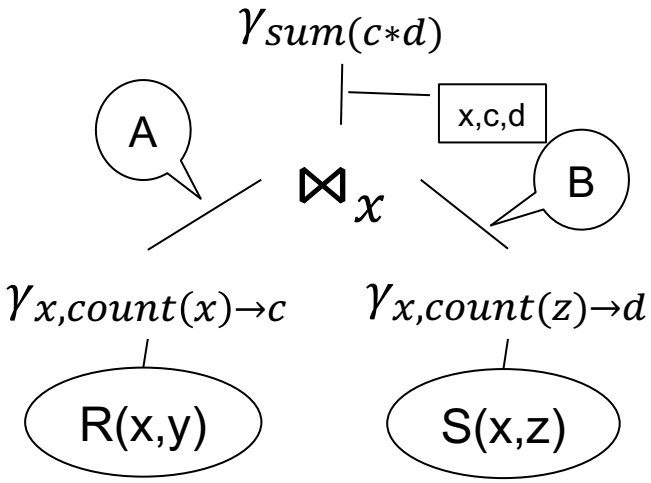

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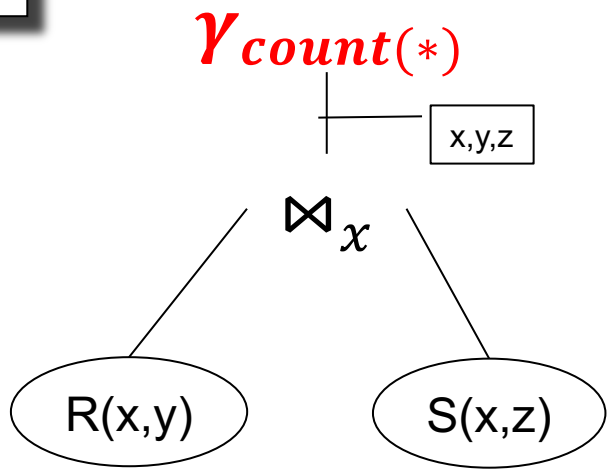


A:

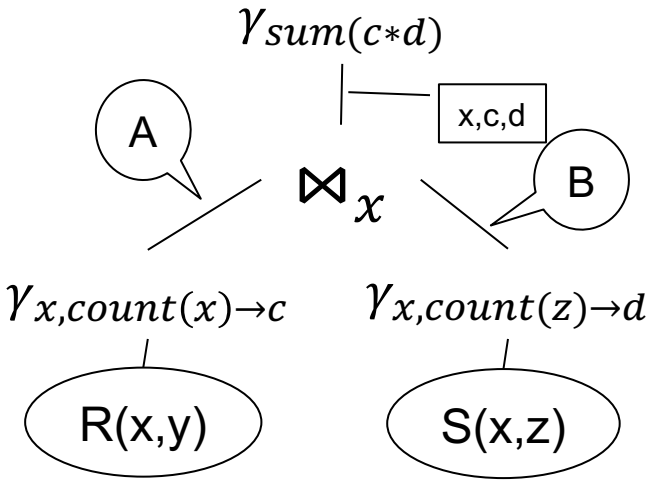
x	c
b	2
f	1
h	1

B:

x	d
b	2
h	1

A⋈B

x	c	d
b	2	2
h	1	1



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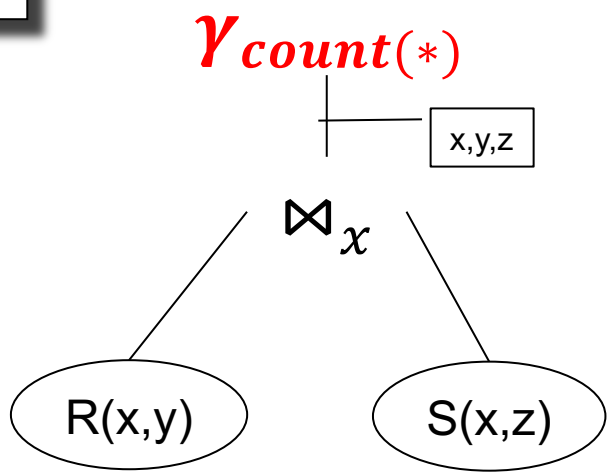
Answer = 5

Runtime = $O(N^2)$



Runtime = ????

A:

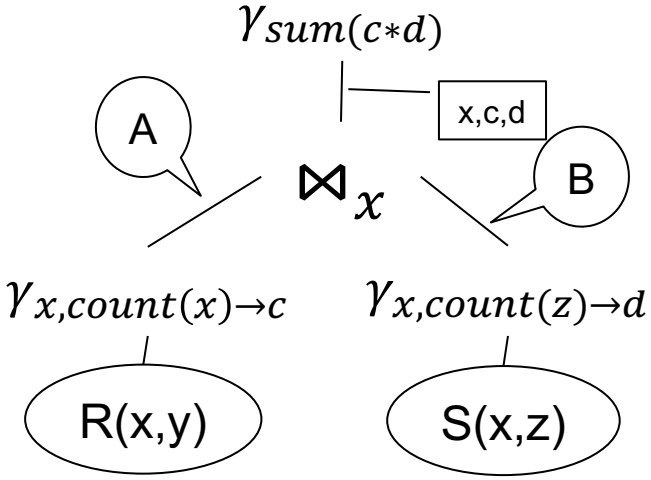
x	c
b	2
f	1
h	1

B:

x	d
b	2
h	1

A⋈B

x	c	d
b	2	2
h	1	1



Generalized Distributivity Law

SELECT count(*) from R, S where R.x=S.x

R:

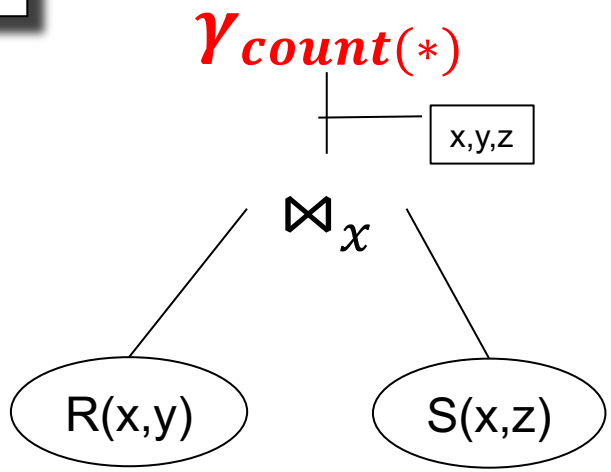
x	y
b	a
b	c
f	d
h	g

S:

x	z
b	g
b	k
h	m

Answer = 5

Runtime = $O(N^2)$



Runtime = O(N)

A:

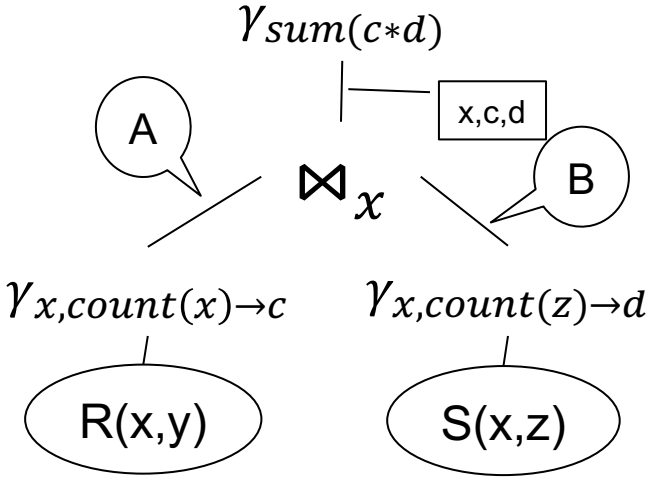
x	c
b	2
f	1
h	1

B:

x	d
b	2
h	1

A⋈B

x	c	d
b	2	2
h	1	1



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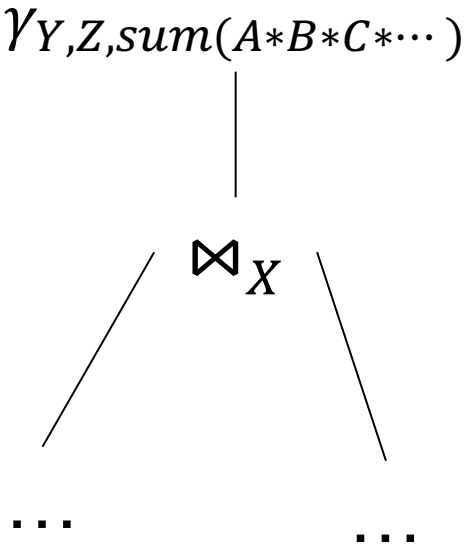

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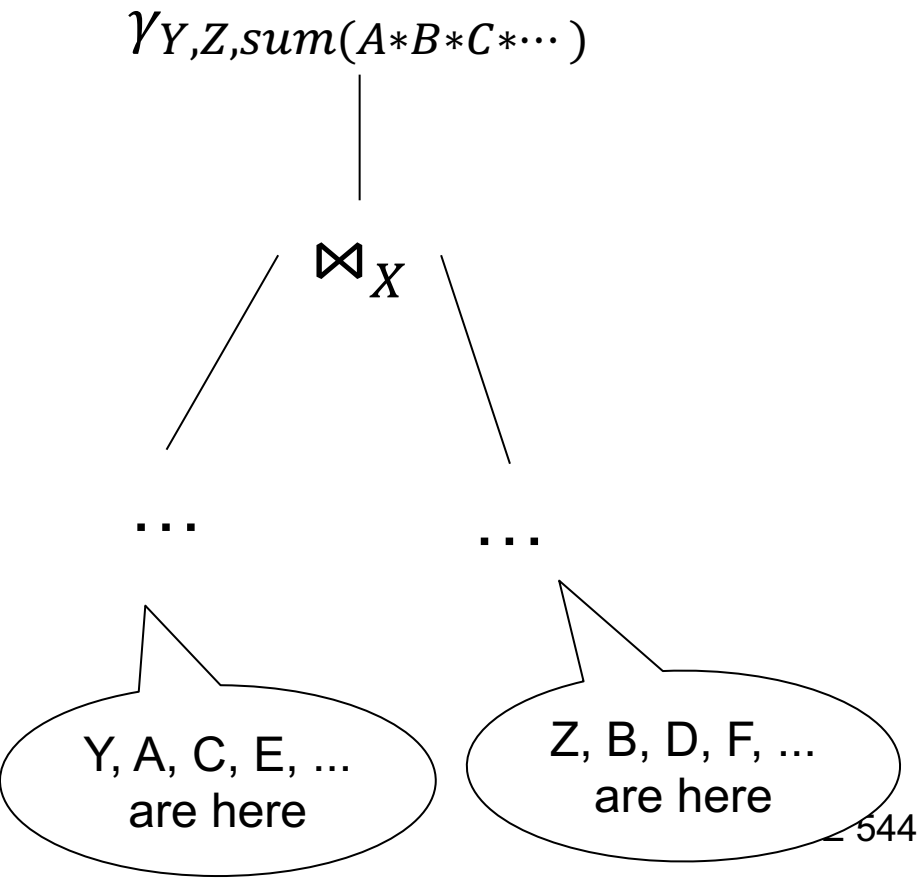
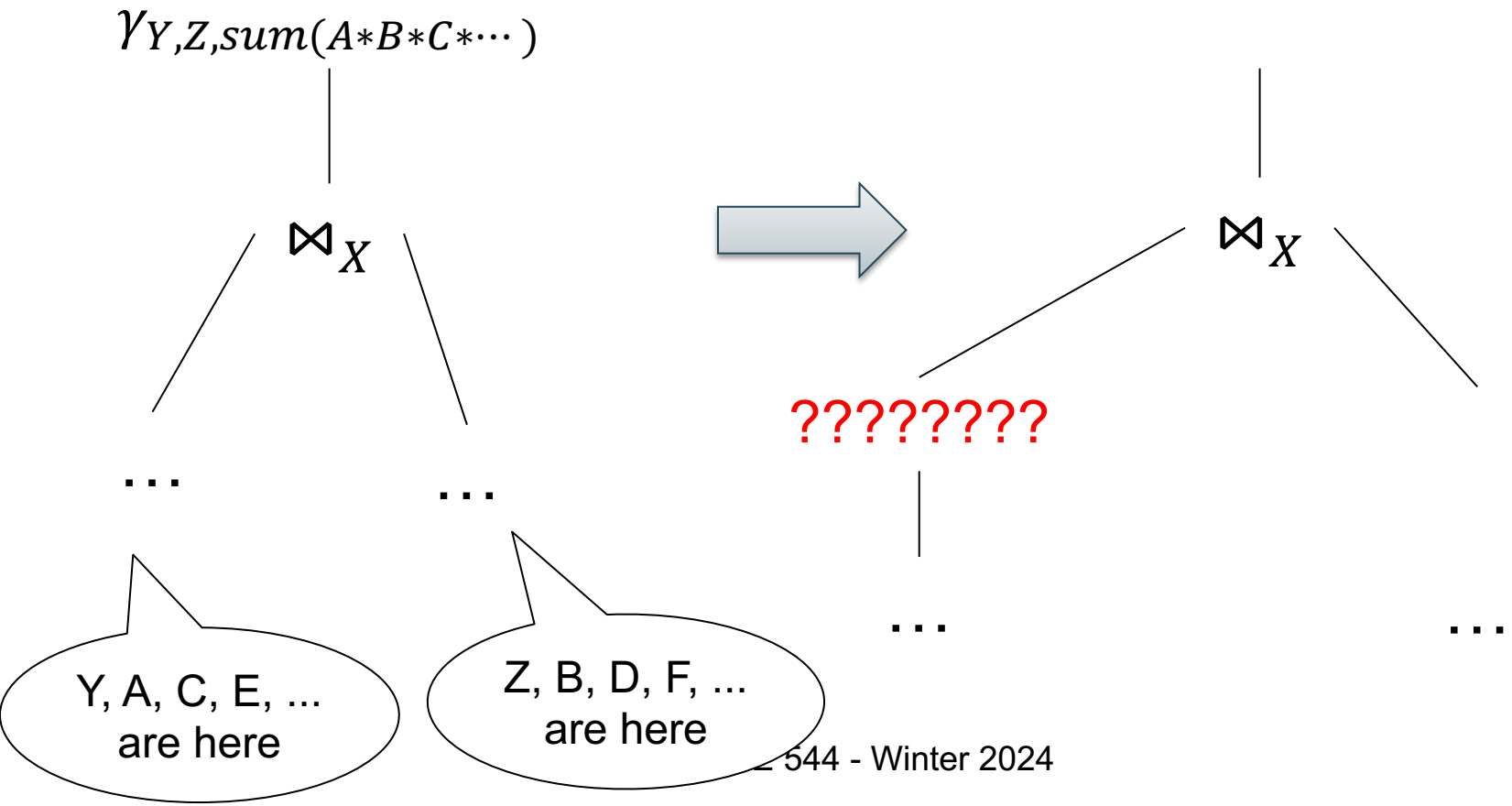
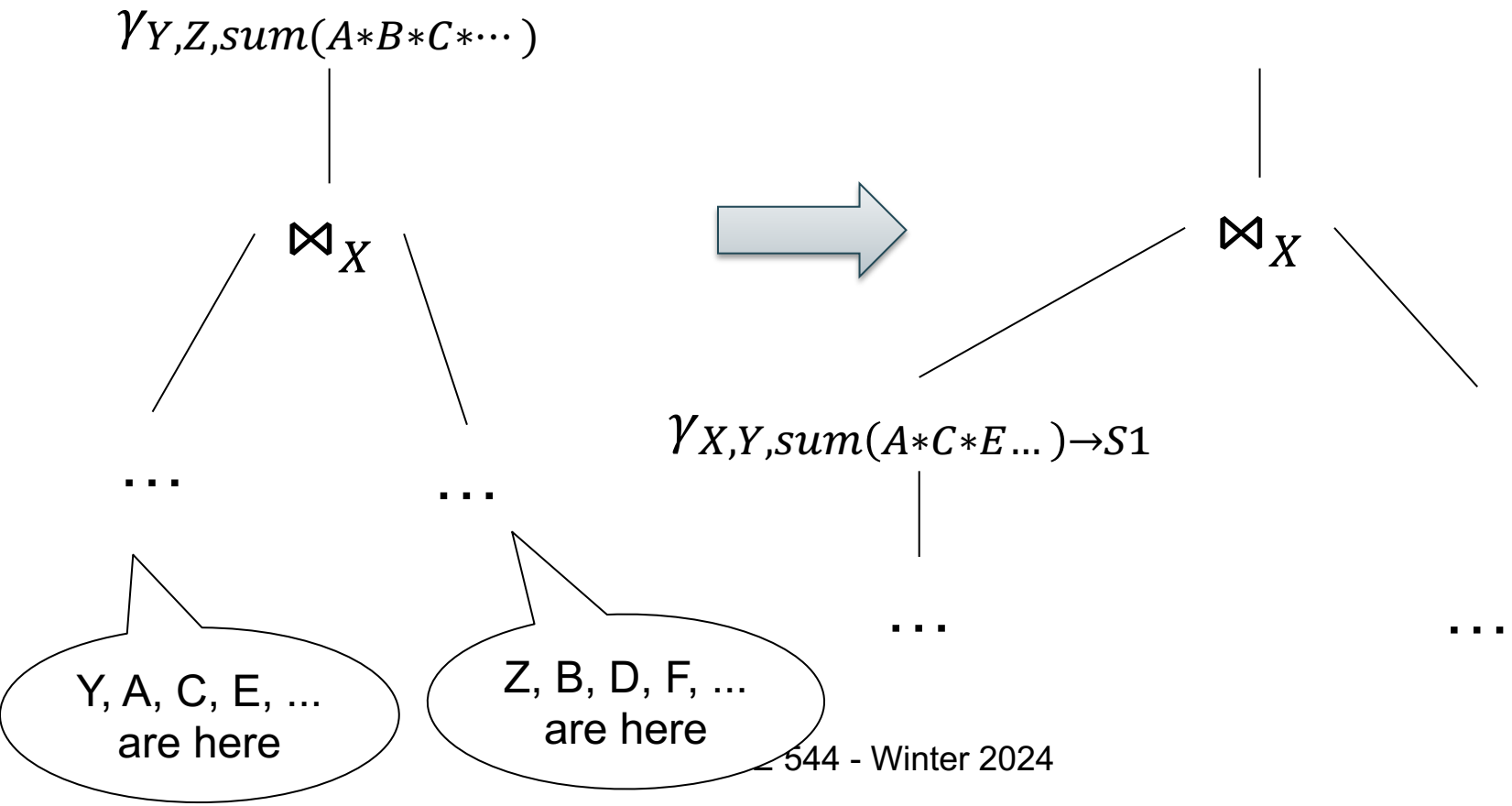


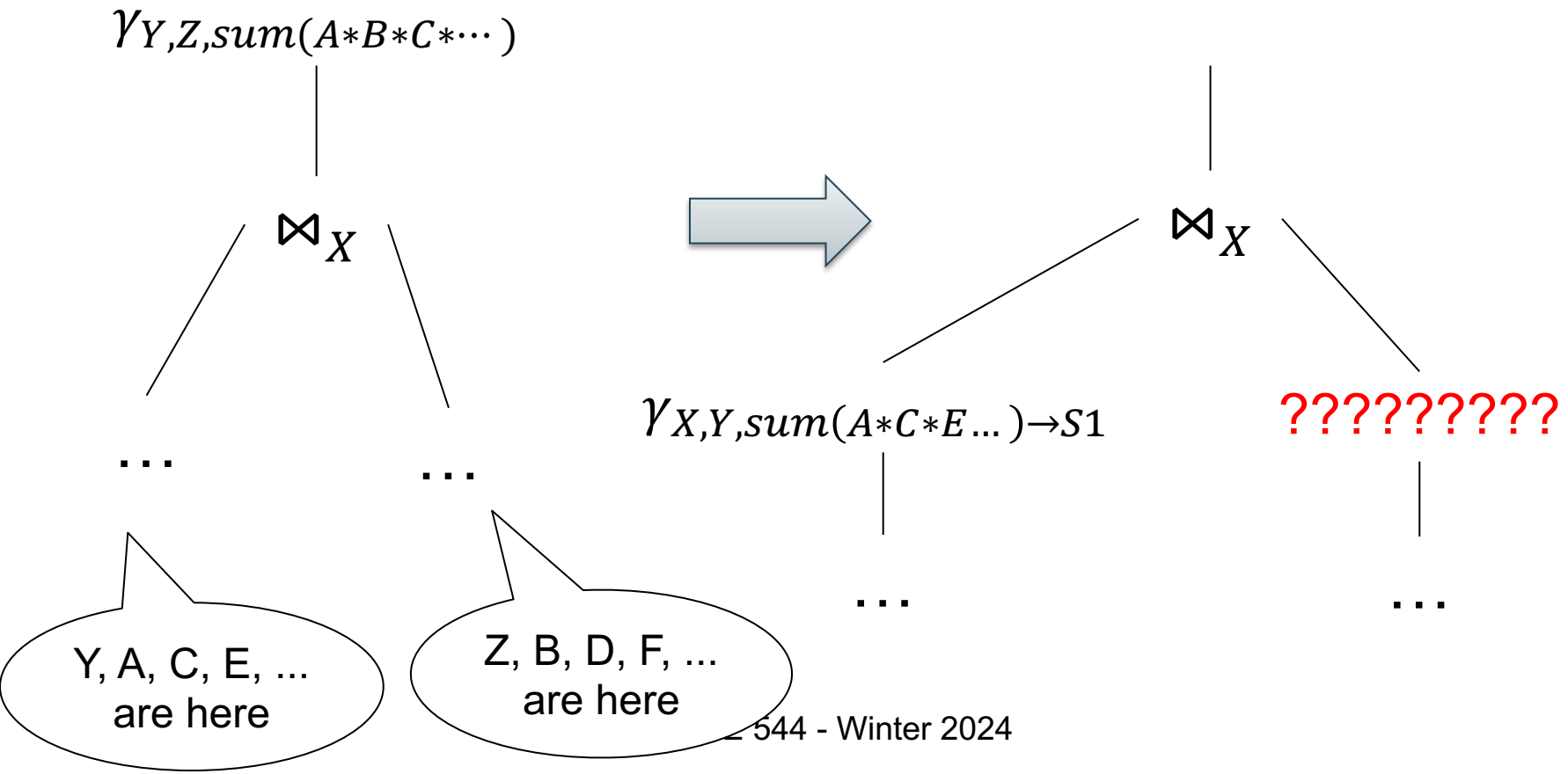
Generalized Distributivity Law



Generalized Distributivity Law



Generalized Distributivity Law



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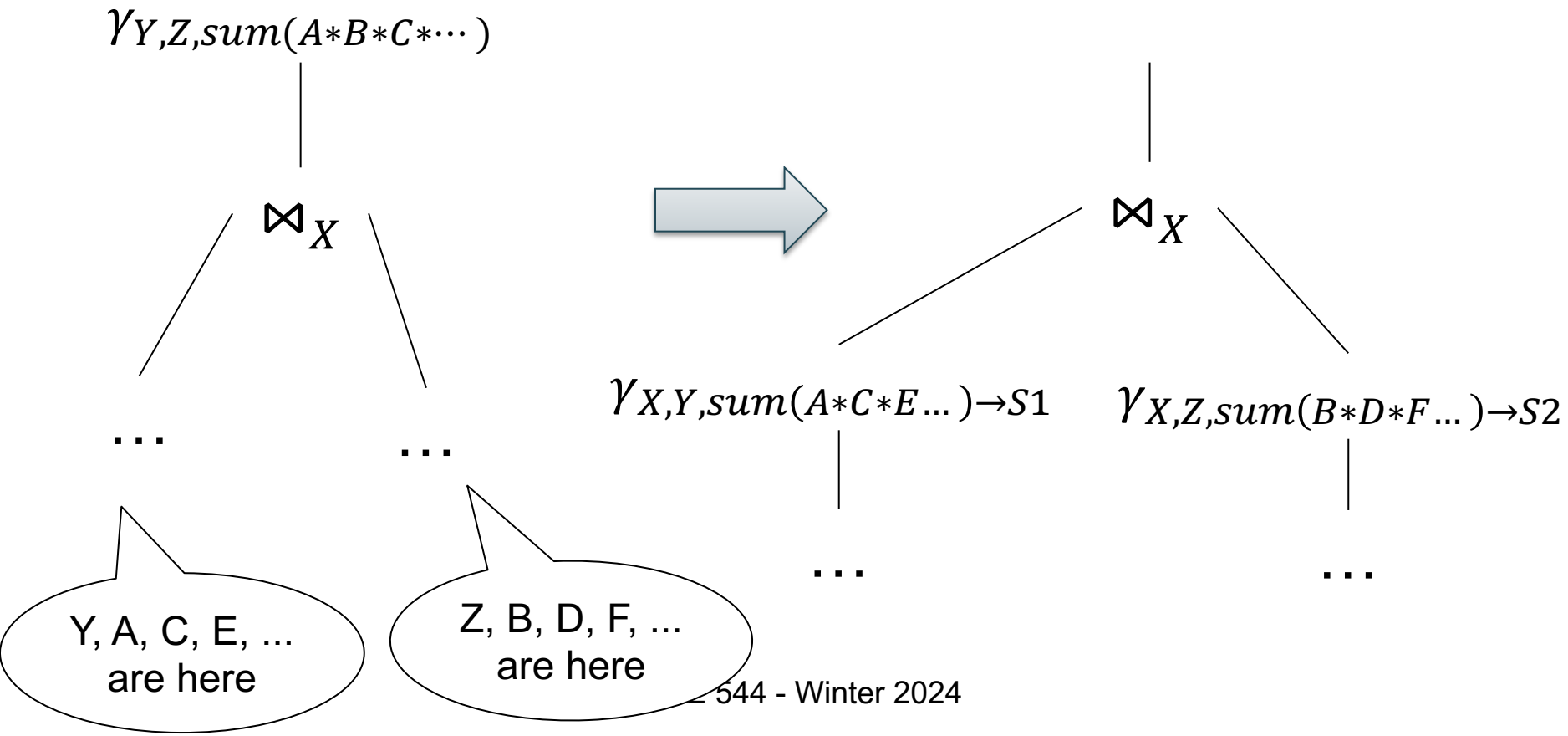
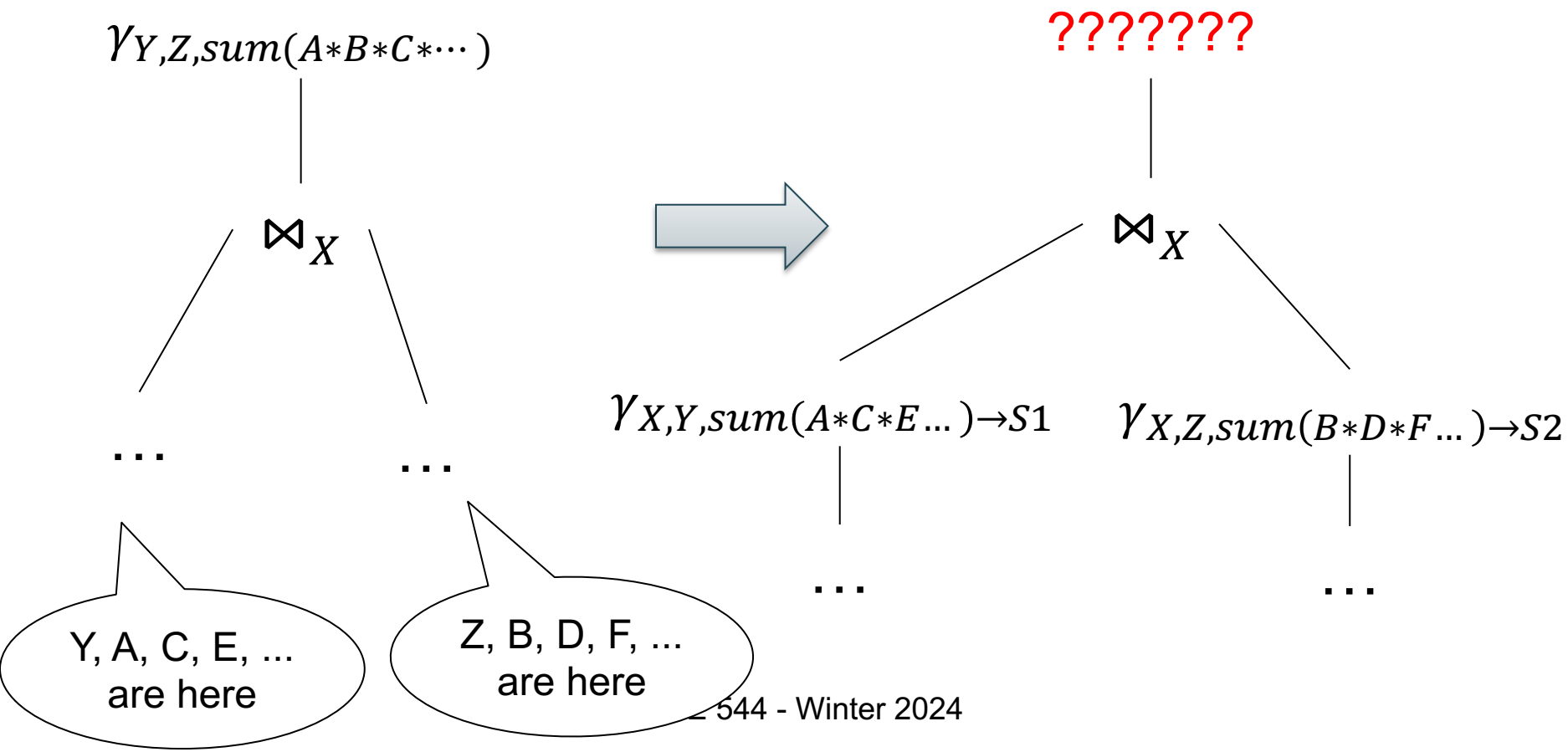
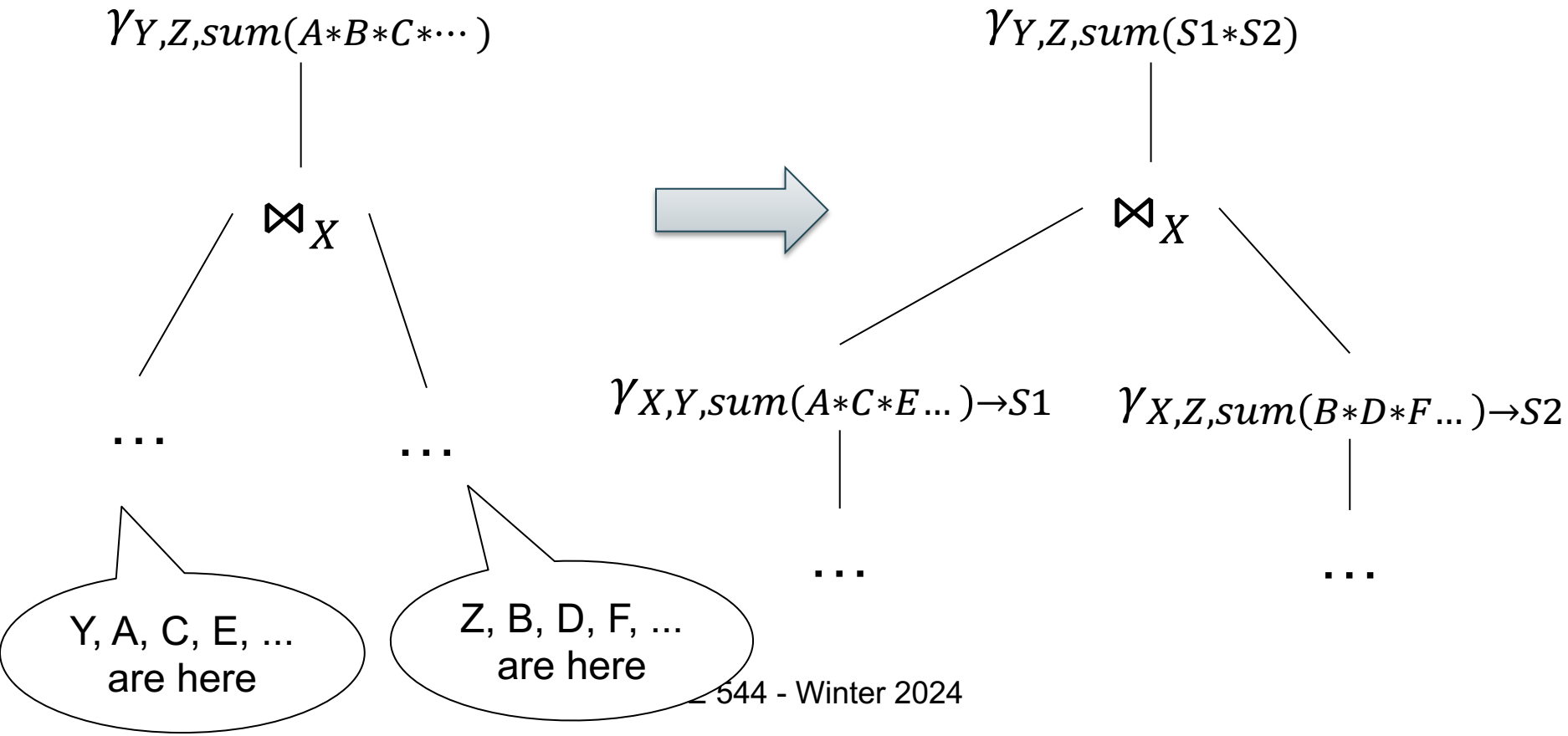


Generalized Distributivity Law



Generalized Distributivity Law



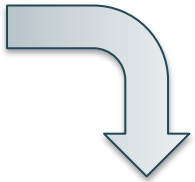
Discussion

- Most DBMS support only some subset of the generalized distributivity law
- Fun activity: check if your favorite DBMS supports it
- Next: a rewrite rule that most DBMS support

Supplier(sid, sname, scity, sstate)
Supply(sid, pno, quantity)

Key / Foreign-Key

```
Select x.pno, x.quantity
From Supply x, Supplier y
Where x.sid = y.sid
```



?

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Key / Foreign-Key

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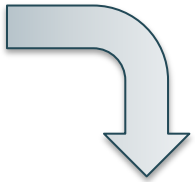

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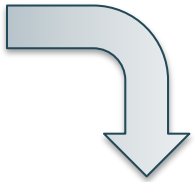

```
Select x.pno, x.quantity
From Supply x
```

Only if these constraints hold:

1. Supplier.sid = key
2. Supply.sid = foreign key
3. Supply.sid NOT NULL

Summary: Rules

$$R \bowtie S = S \bowtie R$$

$$R \bowtie (S \bowtie T) = (R \bowtie S) \bowtie T$$

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In particular, $\delta(\delta(R)) = \delta(R)$

$$\gamma_{X,sum(A*B)}(R \bowtie_{Y=Z} S) =$$

$$\gamma_{X,sum(C*D)}\left(\gamma_{X,Y,sum(A)\to C}(R) \bowtie_{Y=Z} \gamma_{X,Z,sum(B)\to D}(S)\right)$$

Summary: Rules

$$R \bowtie S = S \bowtie R$$

$$R \bowtie (S \bowtie T) = (R \bowtie S) \bowtie T$$

$$\sigma_{C_1 \wedge C_2}(R) = \sigma_{C_1}(\sigma_{C_2}(R))$$

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$$\gamma_{X,sum(B)}\left(\gamma_{X,Y,sum(A)\to B}(R)\right) = \gamma_{X,sum(A)}(R)$$

In particular, $\delta(\delta(R) = \delta(R)$

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$$\gamma_{X,sum(C*D)}\left(\gamma_{X,Y,sum(A)\to C}(R) \bowtie_{Y=Z} \gamma_{X,Z,sum(B)\to D}(S)\right)$$

$$\Pi_{attr(R)}(R \bowtie_{X=Y} S) = R \quad \text{if S.Y key, R.X fk not null}$$

…

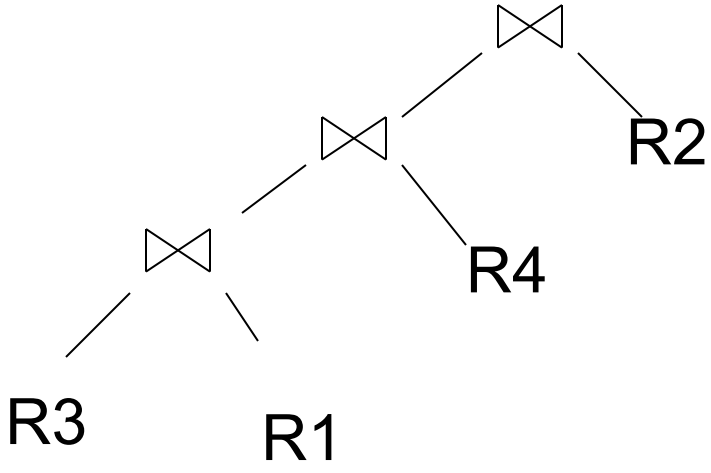
Practice

- Database optimizers typically have a database of rewrite rules
- E.g. SQL Server: about 500 rules
- Rules become complex as they need to serve specialized types of queries

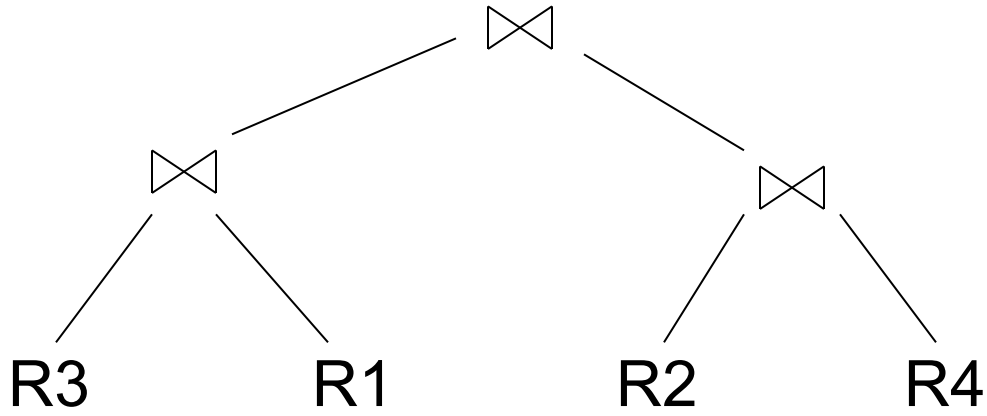
Search Space Challenges

- Search space is huge
- Typical compromises:
  - Left-deep plans
  - Plans without cartesian products

Left-Deep Plans and Bushy Plans



Left-deep plan



Bushy plan

Cartesian Product

- Plan without cartesian product:
$$(R(A,B) \bowtie S(B,C)) \bowtie T(C,D)$$
- Plan with cartesian product
$$\big(R(A,B) \bowtie T(C,D)\big) \bowtie S(B,C)$$
- Some optimizers avoid cartesian products

Query Optimization

Three major components:

1. Search space — today
2. Cardinality and cost estimation — Monday
3. Plan enumeration algorithms — Wednesday